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JOURNAL OF THE AERONAUTICAL SCIENCES

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The Deformation, Recovery and Recrystallization Behavior of Metals

R. H. Hobrock, *Daniel Guggenheim Airship Institute*

(Received January 26, 1936)

It is commonly known that the grain sizes in metals and alloys should be very small so that the metal may be considered as isotropic. Sometimes, however, fabrication processes of forming, annealing, heat-treating, welding, etc., unintentionally cause grain growth in the material, so that there are regions in which the strength properties are different in different directions. In this paper by Dr. Hobrock the conditions under which such large grains will grow are considered, the influence of such large grains on the static and dynamic strength properties are illustrated, and suggestions and precautions against the growth of large grains are discussed.

Included in the paper are some of the results of Dr. Hobrock's own investigations on one of the strong wrought aluminum alloys commonly used in aircraft.

The paper should be of value to designers and those in charge of manufacturing processes in the aeronautical industry.

Th. Troller
Daniel Guggenheim Airship Institute

WHEN metals are forged, rolled, bent, or deformed in some manner, certain properties, both physical and mechanical, are changed. For example, it is well known that cold rolling of a metal increases its hardness and very often its tensile strength. Such cold working of the metal likewise changes the electrical resistance, its galvanic potential, its magnetic characteristics, its elongation, its endurance strength, its damping capacity, and many other of its properties. This is not surprising when it is considered that deforming operations cause displacements of the material in the metal specimens and that such displacements are accompanied by the absorption of energy by the deformed metal.[1] If the internal energy of a metal has been increased by deformation, it is obvious that the driving force tending toward any physical readjustment or chemical reaction leading to a lower energy level will be greater for the cold-worked material than for the material in a completely annealed state. For example, Tammann[2] found that cold-worked copper was less noble than annealed copper and tended to go into solution more readily.

The displacements produced in metals by some form of deformation are sometimes quite apparent, as for example during rolling or upsetting operations. In other cases a definite displacement of material is not so obvious, as in the forming of thin material at a large bend radius. In both cases, however, the material undergoes a plastic deformation and such plastic deformations result in either a displacement of some of the grains of the polycrystalline solid with respect to adjoining grains, or in a displacement within the grains themselves. In most cases both types of displacement occur. In either case, however, the displacements are possible because of the ability of most metals to slip or glide along some of their crystallographic planes. A slip or glide along such planes can (and in most cases does) result in a distortion of the regular arrangement of the atoms in the crystal lattice. Taylor and Elam[3] have shown that it is possible to calculate the unit shearing stress required for a displacement along certain crystallographic planes. When the component of the applied stress lying along the glide plane slightly exceeds the shear stress of the glide plane, a glide or slip will occur.

[1] G. I. Taylor and A. Quinney, *The Latent Energy Remaining in a Metal after Cold Working*, Proc. Roy. Soc., London, (A) 143, 307, 1934.

[2] G. Taumann, *Lehrbuch der Metallkunde*, p. 180, Leopold Voss, Leipzig, 1932.

[3] G. I. Taylor and C. F. Elam, Proc. Roy. Soc., London (A) 108, 28, 1925.

It is apparent from this that the angle which the glide plane makes with the direction of applied stress will influence greatly the value of the applied stress required to produce gliding. In fine grained, polycrystalline metals whose grains have a random distribution of orientations, slippage will occur at some value of applied stress statistically determined by the grain size and random distribution of orientations. If, however, a large number of grains of a polycrystalline solid have, by some means, been so oriented that some of the crystallographic planes in each grain lie in approximately the same plane (preferred orientation), then the stress required to cause slippage may be either greater or smaller than that required in the case of complete random orientation, and is certainly dependent on direction. For example, if the applied stress acts on a specimen with preferred orientation in such a direction that the stress direction itself lies in the glide plane, then the stress required for gliding will be a minimum, since it acts directly in shear along the glide plane. Conversely, if the applied stress acts normal to the glide plane, the stress required for gliding will be a maximum. In a specimen with preferred orientation, it is then seen that the strength properties vary with direction of application of the stress.

Furthermore, if the metal contains large grains, then there exist different strength properties in different directions in the entire volume of material occupied by one grain. This, of course, is equally true regardless of the size of the grain, but in the case that the grains become large with respect to the dimensions of the specimen, then the strength of the whole specimen may be largely dependent on the orientation of one or two grains.

In a crystalline material there is more than one set of planes along which gliding may occur. It is possible to determine experimentally[4] the magnitude of the shear force required to cause slippage along the various planes. In deforming a single crystal, slippage will occur first along that plane in which the component of the applied stress which lies in the plane exceeds the shearing stress required for the slippage. Thus, the planes acting first in slippage are dependent on the orientation of the crystallographic planes with respect to the direction of the applied stress. In crystals with a high degree of symmetry (cubic crystals), the number of equivalent glide planes is so great that gliding occurs first along the weakest plane in almost all cases.

In technical use, the overwhelming majority of metals are in a polycrystalline condition. Such polycrystalline metals behave quite differently from single crystals in regard to their mechanical properties. For example, Fig. 1 shows the great difference in the stress-strain curves for a single crystal of zinc and a specimen made up of many crystals of random orientation. The reason for this great difference is that in the polycrystalline

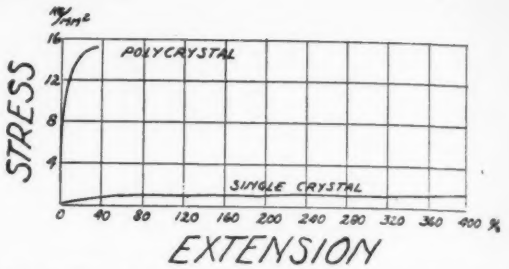

FIG. 1. Stress-strain curves for single and polycrystalline zinc. (M. Polanyi and E. Schmid, Zeit. f. Physik 32, 684, 1925).

material the random orientations of many small crystals act as geometrical obstacles which do not permit slip to take place unopposed. Polanyi and Schmid[5] have shown that a specimen made up of two single crystals, one of bismuth and one of tin, soldered together at different orientations, was greatly hindered in its extension under load. Because of the difference in glide directions, especially near the joint, no uniform gliding occurred, and the portion near the joint stretched very little with respect to the extension in the undisturbed portions of the component single crystals. The hindrance to glide in the polycrystalline materials is then largely responsible for the increase in strength with fineness of grain size. Any operation which orients or partially orients the grains of a polycrystalline material in approximately the same direction tends to produce in the polycrystalline material a condition approaching that existing in a single crystal, and tends, therefore, to lower the mechanical strength. Thus, experiment has shown, in the case of commercially pure aluminum alloy sheet, a fine grained specimen is 40 per cent or more higher in tensile strength than a coarse grained specimen.[6]

Usually a slip along a glide plane is accompanied by an increase in the shearing force necessary to cause further slip along the same plane. This phenomenon is familiar as work hardening and the reasons for its occurrence are not completely understood. However, for purposes of visualization it may here be considered in a simple manner. There are good reasons to believe that all atoms in a crystal are not spaced at exactly regular intervals apart, and that over relatively large distances along crystallographic planes these distances of separation vary slightly, and perhaps in a periodic fashion.[7] Furthermore, there are reasons to believe that there might be more than one type of stable arrangement of all of the atoms in a glide plane.[8] If,

[4] M. Polanyi and E. Schmid, Zeif. f. Physik 16, 336, 1923.

[5] M. Polanyi and E. Schmid, Zeit. f. techn. Phy., Vol. 5, p. 580, 1924.

[6] J. D. Edwards, F. C. Frary, and Z. Jeffries, *The Aluminum Industry, Aluminum Products and their Fabrication*, p. 399. McGraw-Hill Book Company, New York, 1930.

[7] *See, for example*, F. Zwicky, *Secondary Structure and Mosaic Structure of Crystals*, Phy. Rev. 40, 63, 1932; F. Zwicky, *On the Physics of Crystals*, Rev. Modern Physics 6, 193, 1934; and G. I. Taylor, *The Mechanism of Plastic Deformation of Crystals*, Proc. Roy. Soc., London, (A) 145, 362, 1934.

[8] V. Dehlinger, Ann. d. Phys. 2, 749, 1929.

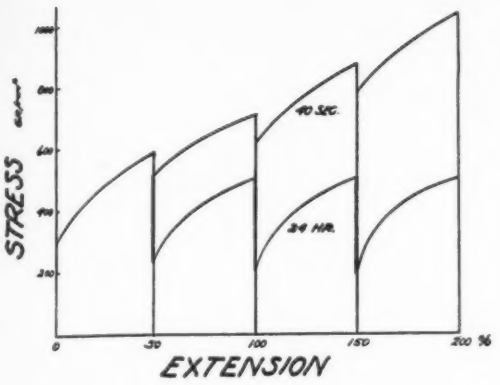

FIG. 2. Stress-strain curves for a single crystal of zinc, showing the influence of two recovery intervals. The load was applied through a spring, and after each extension of 50 per cent the specimen was permitted to rest the indicated length of time, and then the extension continued. During the rest periods the load decreases, due to a further small glide in the crystal. In the case where only 40 seconds were allowed for recovery, the load required for the next extension was always greater than the load for the previous extension, showing the effect of work hardening. The recovery period of 24 hours permitted complete recovery, so that each successive extension began at the same loading. (O. Hasse and E. Schmid, Zeif. f. Physik, 33, 413, 1925).

then, the arrangement of the atoms is instantaneously disturbed by a slip occurring, it can readily be imagined that the rearrangement of the atoms on either side of the glide plane might occur in a slightly different manner and may disturb the "smoothness" of the glide plane—may produce a condition that might be likened to corrugations in the previously smooth plane. The shear force required for slippage along the now corrugated glide surface is then increased and the material is "work hardened."

Now, the atoms in a crystal lattice are in a state of thermal vibration around their average positions at all temperatures above the absolute zero. If the magnitude of these thermal vibrations is sufficient to produce amplitudes of vibration of the same order of magnitude as the disturbances in the atomic arrangement occasioned by the work hardening, then it is possible that after a sufficient length of time the atoms will again resume their initial positions—the glide planes will no longer be warped and the effects of the work hardening will have disappeared. In other words, the material has recovered. Some crystalline materials will recover at room temperatures within rather short times. This is seen in the case of zinc, shown in Fig. 2. The zinc specimens completely recovered after standing 24 hours at room temperature. The recovery after standing but 40 seconds was small. A great many metals require an increase in temperature before recovery occurs to any observable extent.

"Recovery" in its strictest sense is defined as the reversal of the effects of the process of work hardening. During work hardening many of the physical and mechanical properties of crystalline solids change, while during recovery the properties return to their initial state. Recovery, then, does not directly include phenomena that are related to changes in physical or mechanical properties occasioned by solution and precipitation heat-treatments. The term annealing is often broadly used to describe a heating and cooling operation in which recovery may be included together with real annealing. "Stress-relief annealing" is probably a term very nearly synonymous with "recovery-annealing," since the purpose of stress-relief annealing is, of course, to relieve stresses in the crystal lattice. In a number of alloys the temperatures used in stress-relief annealing are such that large changes are made in the physical and mechanical properties of a specimen, due to phase changes in the alloy or due to a change in size and state of dispersion of the interference particles. These changes may be superimposed on any changes due to real recovery so that such latter changes are difficult to observe.

For the sake of brevity, in this paper a term "temper-relief" will be defined as a heating and cooling operation carried out for the purpose of causing phase changes in an alloy, or changes in the state of dispersion of interference particles in an alloy, in order to approach more or less closely the physical and mechanical properties of the predominating metallic constituent. For example, temper-relief of a duralumin-type alloy would be a treatment designed to remove as completely as possible the effects of the small additions of copper, etc., that are largely responsible for the properties of the alloy, and to approach as nearly as possible the properties of the major constituent, aluminum.

Recovery and temper-relief are then two different phenomena. It is possible that one of the two might be accomplished without the other. For example, in a previous paper[9] the author has shown that temper-relief may be carried to completion without relieving the stresses in the crystal lattice; that is, without the lattice having recovered. The curves illustrating this have been reproduced in Fig. 3. In this case X-ray diffraction patterns showed that specimens of a deformed dural-type of aluminum alloy did not recover when heated to 345° C. unless the initial cold deformation had exceeded about 15 per cent. The curves shown in Fig. 3 do indicate a minimum hardness for specimens annealed at this temperature, regardless of the initial cold deformation. However, the specimens deformed 15 per cent and less showed a greater hardness than those initially deformed more than 15 per cent. This higher hardness may then be attributed to the fact that the crystal lattice of those specimens deformed 15 per cent and less had not recovered at the annealing temperature of 345° C. This remaining stress or deformation in the crystal lattice is of importance if the material is to be heat-treated later, since by heating to the

[9] R. H. Hobrock, *On the Recovery of a Strong Aluminum Alloy*, Daniel Guggenheim Airship Institute Publication No. 2, p. 80, 1935.

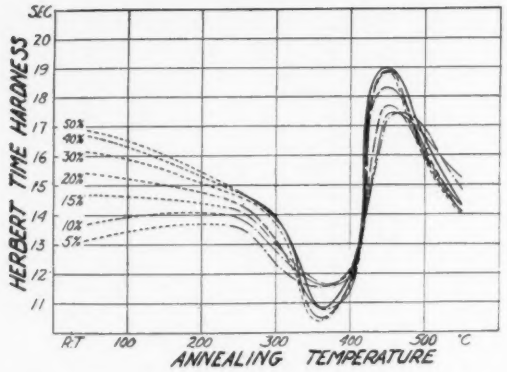

FIG. 3. Curves showing the hardness of specimens of a strong aluminum alloy that had been annealed at 525° C., deformed by compression the indicated amounts and then annealed at various temperatures.

higher temperatures necessary for the solution-heat-treatment the metal can recrystallize. This will be discussed in greater detail later.

If a small beam of X-rays is passed through a sample of a crystalline solid, the regular arrangement of the atoms in the solid will act as a diffraction grating, and due to interference and reinforcement of the diffracted beam, lines or spots will occur on a photographic film properly placed, in accordance with the well-known diffraction equation

$$n\lambda = 2d \sin\theta$$

in which n = the order of the spectrum;
λ = the wave length of the X-rays;
d = the distance between the crystallographic planes acting to produce a particular line or spot in the pattern;
θ = the angle of incidence of the beam on the planes acting in diffraction.

If the crystal lattice is not distorted, sharp lines or spots will appear (Fig. 6). But if the lattice has been distorted by working in some manner, then the distances between the atoms (and therefore between the crystallographic planes) will not be exactly uniform and what might otherwise have been a spot on the diffraction pattern will have become a streak. This is known as asterism. Asterism in a pin-hole diffraction pattern is then an indication of a distorted lattice. This is especially true in the case that the diffraction pattern has been made of a polycrystalline material. The X-ray diffraction method may then be used to discover lattice distortions and also provides a method for determining what heating operations are necessary for the relief of such distortions. A typical curve showing the temperatures (for a heating time of 15 hours) and the corresponding deformations that have been relieved by the treatment, are shown in Fig. 4 for a dural-type alloy.

From these curves it is seen that small deformations require higher temperatures for their relief—indeed, to

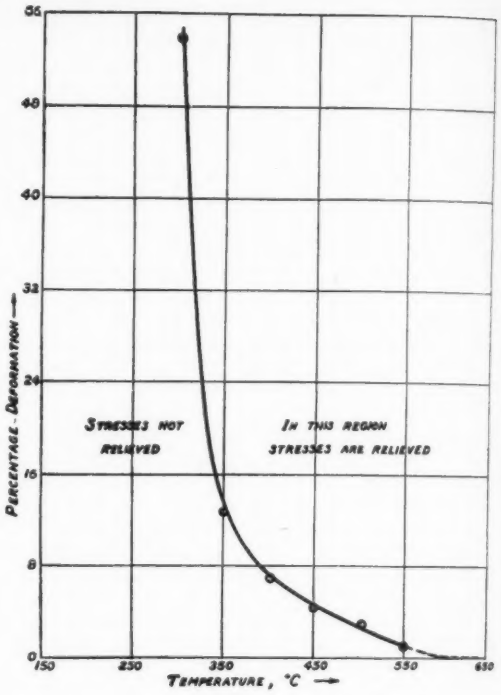

FIG. 4. Curve showing the amount of cold deformation and the corresponding minimum annealing temperatures required to permit recovery of the crystal lattice. (From X-ray diffraction patterns).

such an extent that very small deformations are perhaps only relieved at the melting point. This is readily understandable when it is considered that the greater the distortion of the lattice, the greater is the amount of potential energy stored in the lattice, and therefore the greater the tendency toward readjustment to a condition of lower energy. In the case of very small distortions the additional potential energy stored in the lattice is small and there is but a very small tendency toward readjustment; therefore higher thermal agitation (higher temperatures) is necessary to induce and facilitate the readjustment.

The discussion of deformation and recovery might then be summarized as follows:

(1) The energy content of a metal or alloy is increased by cold-working and is held bound in the metal as potential energy. Upon heating the metal this potential energy is released as heat.

(2) Deformation occurs by slippage along certain crystallographic planes in the metal crystals. These are known as glide planes. If a slip has occurred along a glide plane, the shearing stress along the glide plane required for a further deformation is increased. This accounts for the phenomenon of work-hardening.

(3) The increase in potential energy of a metal due to cold work results in an increased tendency to react and to readjust the lattice. Therefore the metal becomes

less noble, has an increased speed of reaction with solvents, increases in electrical resistance, etc.[10]

(4) Polycrystalline metals are quite different from single crystals in their mechanical behavior, because the many grains of random crystallographic orientation act geometrically to hinder easy glide. The mechanical properties of polycrystalline metals will then depend largely on the size of the grains.[11]

(5) As the result of slippage, the crystallographic planes change a small amount in the distances of their separations and are usually not uniformly spaced. Because of this, a pin-hole X-ray diffraction diagram made of such a deformed specimen will not permit the diffracted beam of X-rays to reinforce at exactly one place, but will spread out. This is known as asterism, and may be used as an indication of the condition of distortion of the crystals.

In addition to this, it is interesting and important to note that there is an increased tendency for foreign atoms (for example, resulting from the separation of solute atoms from a supersaturated solid solution) to separate out at places of high potential energy within the crystal. It is well known that if an alloy is compounded of one material soluble in another constituent at high temperatures, but decreasingly soluble at lower temperatures, and that if such an alloy is cooled very rapidly from the high temperature, it is possible to produce a supersaturated solution at low temperatures. Often this supersaturated solution will slowly separate at room temperatures, with a freeing and coagulation of the solute constituent. If the temperature of the supersaturated material is increased, the thermal energy is increased and the separation goes on more rapidly. This is somewhat similar to the case of a deformed lattice. Those planes along which slippage has occurred have locally increased in potential energy, and it is along such planes that separation from a supersaturated mixed crystal goes on most readily, with the result that often the separated constituent collects there in unusual amount. By proper etching these separations may be seen and then show the places where slippage has occurred. Such slip lines made visible are known as Lueder lines.[12]

Recrystallization

In the first portion of this paper deformation and recovery were briefly discussed. In this section recrystallization will be considered. Recrystallization is the change in size and/or orientation of a crystalline material at temperatures below the melting point. It is a phenomenon of practical importance in the working and heat-treatment of commercial polycrystalline metals in that it influences the grain size of the material. Some metals, such as iron, have several crystal forms, stable within certain temperature ranges. These different crystal forms are known as allotropic, and the change from one crystal form to another, as allotropic changes. Thus iron changes from a body-centered cubic form (alpha iron) to a face-centered cubic form (gamma iron) at 908.5° C. This change is accompanied by changes in the position of the atoms. In the case of iron, motions of translation of the order of 0.45×10^{-8} cm. and 0.75×10^{-8} cm. are necessary. If a specimen of metal which undergoes an allotropic change is cooled very rapidly from a temperature above the allotropic change temperature, a very rapid change to the crystal form stable at the lower temperature is necessary, and the crystal will start such readjustment from many different places. This then results in a material with many small grains of the crystal configuration stable at the lower temperature. This is the phenomenon of "grain refinement" commonly carried out with many of the ferrous alloys.

However, a great number of metals do not undergo allotropic changes—among these are aluminum and the aluminum alloys—so that the grain size is determined by the rate of cooling from the melt (in the case of castings), or by the combination of mechanical working and heating operations to which the material has been subjected; that is, the grain size is determined by the recrystallization behavior of the particular metal or alloy.

All technical metals contain foreign atoms, sometimes as unavoidable impurities and sometimes added as alloying agents. When the metal freezes from a melt, these atoms are rejected more or less, since they cannot fit perfectly into the crystal lattice of the parent metal. This results in an accumulation of foreign atoms at the boundaries of the growing crystal, and therefore when the melt has completely frozen, the foreign atoms are found in the grain boundaries. If the melt has been cooled fairly slowly, so as not to produce high internal stresses upon cooling, then subsequent reheating of the cast specimen will not produce a change in grain size. But if the cast specimen is first deformed in some manner and then heated to a proper temperature (below the melting point), the grain boundaries will have been broken through at various places (if the deformation had been sufficient), and there will exist places on certain crystallographic planes where slippage has occurred and where the potential energy has been increased. At any temperature above the minimum recrystallization temperature, rearrangement of the atoms will start from the planes of high potential energy, and it is possible that this rearrangement will continue to the extent of growing a new grain, even growing through the ruptured grain boundary and producing a very large grain. If the deformation has been large, then there are many places of increased potential energy within a grain and at the recrystallization temperature new rearrangements

[10] G. Greenwood, *The Effect of Cold Work on the Physical Properties of Aluminum with Special Reference to Electrical Resistance*, Zeif. f. Kristall, Vol. 80, p. 481, 1931.

[11] *See Reference* 6.

[12] W. Koester, Archiv. f. d. Eisenhuett. 3, pp. 553 and 649, 1928.

are possible from many different places. In this case it is apparent that the recrystallized structure may have a smaller grain size than the original structure.

Recrystallization may then either increase or decrease the grain size, depending on the severity of the deformation of the material and upon the temperature at which the recrystallization is carried out. Furthermore, it is easily seen that the size to which such crystals can grow is dependent on the amount and kind of the foreign atoms, and upon the rate of heating to the recrystallization temperature. In the case of the strong aluminum alloys, for example, it seems that an increase in the magnesium content operates to hinder the production of large crystals upon recrystallization.

The recrystallization behavior of a metal or alloy can be represented in a recrystallization diagram such as is shown in Fig. 5. Such a diagram shows the relation between the amount of deformation, the recrystallization temperature, and the grain size, as determined experimentally. Any particular diagram of this kind is dependent upon the conditions of the experimental procedure used in determining it. For example, the diagram shown in Fig. 5 was determined as follows:

(a) The time of heating at the various temperatures was 15 hours.

(b) The deformation was the percentage decrease in height of small cubes (10 mm. on each side) and small cylinders (0.5″ diam × 1″ high) deformed in compression between highly polished and lubricated steel plates.

(c) The crystal size was determined by counts at the center of an etched specimen, made by cutting the compressed sample in half along the direction of compression. A calculation from the crystal counts, based on the assumption that each grain was cubical, gave the dimension of the side as shown in the diagram.

(d) The boundary in the temperature-deformation plane was determined by X-ray diffraction patterns. Only the data from specimens that had completely recovered (returned to an undistorted lattice) were included in the diagram. (The curve used in determining the boundary in the temperature-deformation plane is shown in Fig. 4.)

If very thin specimens are used, or if the deformation is carried out in another manner (such as rolling), the values indicated upon the axis of the diagram will change, but the general appearance of the diagram will remain the same. It is important to note that there is a region of critical deformation, in which the crystals grow large upon recrystallization. The low temperature portion of this diagram (below 400° C) is perhaps not legitimately a portion of the real recrystallization diagram, but is only due to fragmentation of the polycrystalline metal upon cold working and subsequent recovery at the indicated temperatures. The reasons for this belief are discussed in another paper by the author.

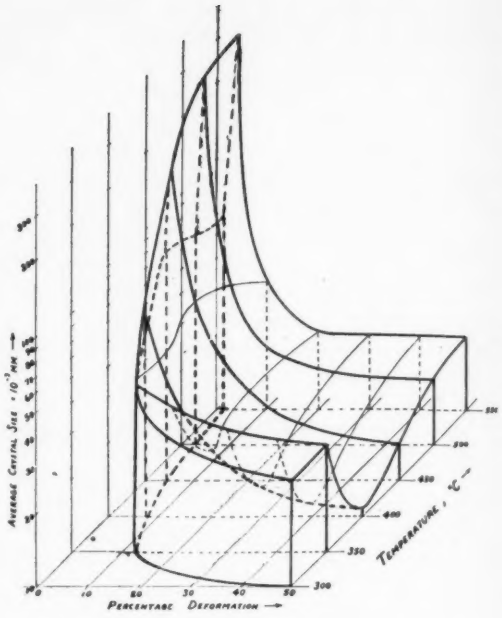

Fig. 5. The recovery-recrystallization diagram for a strong aluminum alloy with a nominal composition of 4 per cent Cu., 0.5 per cent Mn., 0.5 per cent Mg., and remainder Al.

Since, however, this recovery behavior is of interest and of practical importance, it is included in the complete diagram and the diagram called a "recovery-recrystallization diagram." The crystal size in the recovery portion of the diagram is dependent to a large degree on the crystal size of the material before the deformation was made, as well as upon the amount of deformation and the temperature.

The importance of crystal size as a determining factor in the static and dynamic strength properties of metals is well known[13] and has been considered briefly in the first section of this paper. Precautions are usually taken, in ordering material, to specify a maximum allowable grain size, and yet it sometimes occurs that during subsequent fabrication the grain size is unintentionally increased a great deal. If a single grain in the material approaches in size the dimensions of the cross-section of the piece, then there is a chance that the static properties of the piece will depend largely upon those of a single grain. This is especially true if the material in question is sensitive to notches—that is, is sensitive to stress concentrations and has a low dynamic ductility (damping capacity). In this latter case, the slippage in one favorably oriented grain (especially near the edge) may, in effect, produce a stress concentration in the adjoining material similar to that occasioned by a notch, and may in this way promote failure under static loading. Furthermore, it frequently happens that those

[13] H. J. Gough, *Crystalline Structure in Relation to Failure of Metals, (Marburg Lecture)*, Proc. A.S.T.M., Part II, Vol. 33, p. 3, 1933.

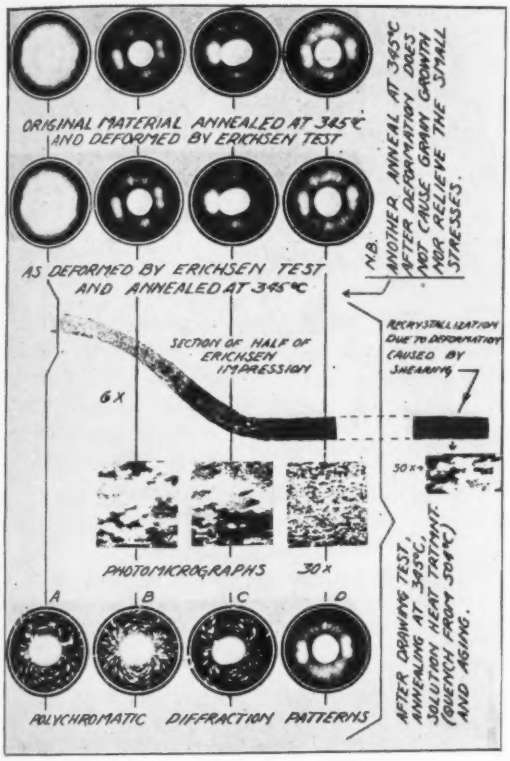
ORIGINAL MATERIAL ANNEALED AT 345°C AND DEFORMED BY ERICHSEN TEST
AS DEFORMED BY ERICHSEN TEST AND ANNEALED AT 345°C
N.B. ANOTHER ANNEAL AT 345°C AFTER DEFORMATION DOES NOT CAUSE GRAIN GROWTH NOR RELIEVE THE SMALL STRESSES.
SECTION OF HALF OF ERICHSEN IMPRESSION
RECRYSTALLIZATION DUE TO DEFORMATION CAUSED BY SHEARING
6 X
30 X
PHOTOMICROGRAPHS 30 X
A
B
C
D
POLYCHROMATIC DIFFRACTION PATTERNS
AFTER DRAWING TEST, ANNEALING AT 345°C, SOLUTION HEAT TREATMENT (QUENCH FROM 505°C) AND AGING.

FIG. 6. Recovery and recrystallization behavior of a strong aluminum alloy.

places where recrystallization to large grains has occurred are exactly those points in which some stress concentrations will occur in a piece, so that an especially favorable condition for failure might occur.

Consider as an example the photo-micrographs and diffraction patterns shown in Fig. 6. It was the object, in this illustration, to undertake a deforming operation on a dural-type of alloy and to subsequently heat-treat the alloy in the usual manner. The deformation was made on an Erichsen machine used in testing the deep drawing properties of sheet metals. A steel ball 7/8" in diameter pressed the metal into a circular opening 1" in diameter. The metal was deformed in this fashion while in the dead soft condition. Subsequent heat-treatment produced a grain growth in the alloy seen in the enlarged cross-sectional picture. Some of the larger grains are seen to extend almost entirely through the section of the material.

In another similar experiment, an attempt was made to relieve the internal stresses in the deformed grains at a temperature below the recrystallization range. If such relief can be accomplished, then subsequent heat-treatment at the higher temperatures necessary for the solution-heat-treatment would produce no grain growth[14] since there would be no places of high potential energy in the grain from which rearrangement of the

[14] *See Reference* 9.

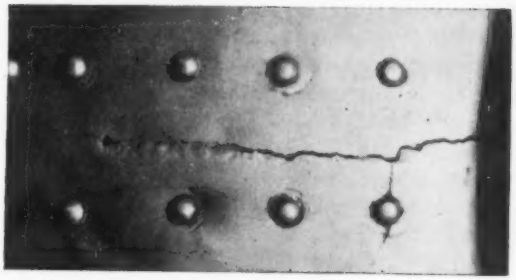

FIG. 7. Fatigue crack in engine cowling. (An attempt had been made to stop progress of the crack).

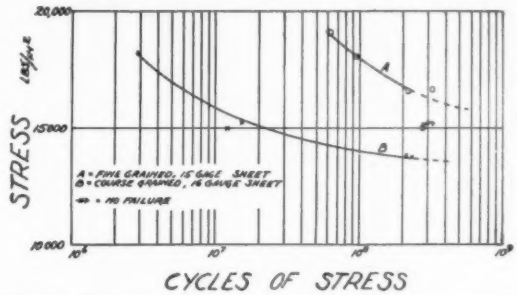

FIG. 8. Fatigue curves for a fine-grained and a coarse-grained strong aluminum alloy. (R. L. Templin, Proc. A.S.T.M., Vol. 33, Part 2, 1933).

atoms might start. The treatment prescribed for a stress-relief anneal of this alloy is heating at 345° C. and slow cooling. From the recovery diagram for this alloy (Fig. 4), it is seen that such an annealing treatment might be expected to relieve all internal stresses above values corresponding to a deformation of about 15 per cent. But it is further seen from the diagram (Fig. 5) that the small deformations will not be relieved at this temperature, and these small deformations are those conducive to the growth of large grains at the solution heat-treatment temperature of about 505° C.

The diffraction diagrams and the photo-micrographs in Fig. 6 show that this prediction was true. The annealing at 345° C. did not relieve the low stresses, so that upon subsequent heat-treatment large grains grew.

This recrystallization behavior is of practical importance in many fabrication processes. For example, Fig. 7 shows a typical failure in an engine cowling for an airplane, and the attempt to repair it by riveting a sheet over the crack. This failure occurred after less than 25 hours flying time, and had every appearance of a fatigue crack. It started from a region where the grain size was large and where the fatigue stresses were very likely the highest. The method of fabricating this cowling is not known to the author, but it is very likely that the forming and annealing operations produced the large grain size by recrystallization and that the region of large grain size was also the region subjected to the highest fatigue stresses. The correspondence of these two would produce a condition especially favorable to

fatigue failure, as may be seen from the diagram of Fig. 8, where it is seen that the endurance limit of that alloy in the coarse grained condition is about 21 per cent lower than in the fine grained condition. Several cowlings of this kind failed in the same way. Redesign of some portions of the cowling is probably indicated. However, it appears desirable to also avoid the large grain size and to thereby take advantage of the increased endurance properties thus achieved.

There are various other common occurrences of grain growth. For example, the shearing of a metal may produce a deformation near the edge that will result in large grains upon subsequent heat-treatment. This is seen in Fig. 6. In this case a sheet of dural 0.054″ thick was sheared on a power shears and subsequently heat-treated and aged. The photo-micrograph shows the growth of large crystals near the sheared edge, due to the deformation occasioned by the shearing and the subsequent heat-treating temperature. Other cases of grain growth that have been observed include a gasoline tank, bent to shape, riveted, and the rivets then sealed by welding. The temperature rise occasioned by the welding was sufficient to cause recrystallization in the section that had been deformed by bending. The tank failed in that a fatigue crack developed in the bend. In another instance a small bracket was formed and welded to a piece of tubing. In this case again, the welding temperature caused recrystallization to very large grains, extending in some cases through the whole section of the bracket.

From the discussion so far it might appear that the growth of large grains in some cases is almost unavoidable, since (from the diagrams) the relief of the small stresses is impossible, except at recrystallization temperatures, and since it is the small stresses that produce the largest grains. However, in most cases large grain growth can be prevented by one of the following expedients:

(a) Carry out forming operations *after* heat treatment.[15] This is not always possible with different alloys, or it may not be possible because the severity of the cold working requires material in the dead soft condition or may require intermediate stress-relief annealings. In the case of dural, however, forming operations can be carried out immediately after the quench from the solution heat-treatment and before precipitation hardening has proceeded to any extent—usually from within 30 minutes to a few hours after the quench. During a short time immediately following the quench, the ductility of these alloys is almost that of the dead soft condition. Cold working, however, accelerates the precipitation hardening and reduces the ductility of the material. Forming operations carried out immediately after the quench do not, of course, prevent deformation of the lattice and the presence of internal stresses in the material. This simply prevents recrystallization because no subsequent heatings to recrystallization temperatures are contemplated. If, for some reason, the temperature of a deformed specimen is increased later, after the deformation (for example, by welding), recrystallization will take place.

FIG. 9. Photo-micrograph showing large grain growth in a low-strength aluminum alloy, caused by a single hammer blow on the specimen while at a temperature within the recrystallization range.

(b) Make the deformations great enough so that upon recrystallization small crystals will grow. This is again apparent from the diagram. It may be seen that if deformations of above about 20 per cent are made, the crystal size upon recrystallization is small. Very often it is possible to increase the amount of cold work by hammering. Thus, in making a bend, for example, the bend may be hammered in such a way as to increase the internal stresses, so that upon subsequent heat-treatment, recrystallization will cause small crystals to grow.

(c) Heat the material that has been deformed and is to be heat-treated, to the required temperature very rapidly.[16] It is the purpose of such very rapid heating to quickly arrive at the required temperature, so that recrystallization may start from many different points and so prevent large grain size. Obviously, if a specimen is heated slowly, those places of particularly high potential energy will start rearrangement first, and the rate of this rearrangement (rate of recrystallization) may exceed or keep pace with the rate of heating, so that large crystals can grow. If, on the other hand, the high temperature is arrived at very quickly, then recrystallization may start from places with quite a range of differently increased potential energies, and so result in small grain size. It is often difficult to really apply this expedient, since (1) it is often practically impossible to achieve such a high heating rate in specimens of any great size, and certainly in specimens of any considerable thickness; and (2) the rate of recrystallization of many metals and alloys is very high, so that heating to exceed it is practically impossible. The photo-micrograph of Fig. 9 illustrates how rapidly recrystallization can go on. In the case of the specimen shown in Fig. 9, the sample was heated within the recrystallization temperature range, was quickly removed from the furnace, and given one quick blow with the hammer, and was then cooled by quenching. In spite of a rapid sequence of these operations, large crystals grew.

[15] *See Reference 6, p. 238.*

[16] H. Rohrig, Zeit. f. Metallkunde, Vol. 16, p. 265, 1924.

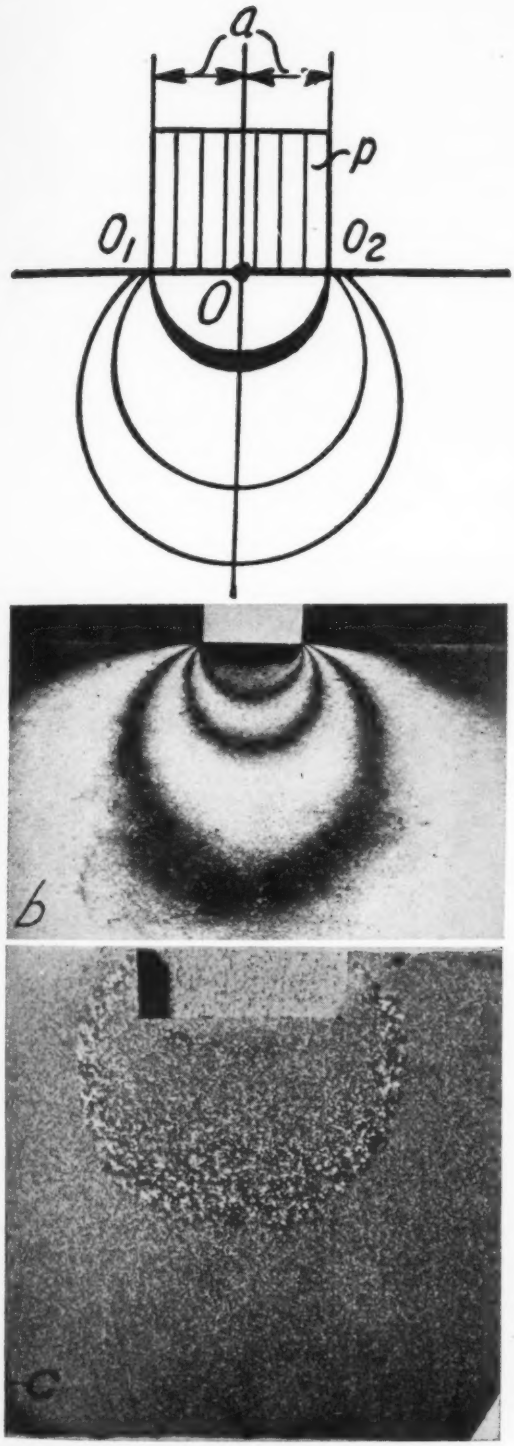

FIG. 10.
a. Theoretically derived isochromatic lines.
b. Isochromatic lines from photo-elastic method.
c. Recrystallized zones in an aluminum alloy after deformation by a punch and heating to 500° C.

(a. and b. from Plasticity, by A. Nadai. *Courtesy United Engineering Trustees, Inc.*).

(d) Finally, if none of the other expedients for preventing large grain growth are possible of application, it may be necessary to select an alloy of different composition, in which grain growth is hindered by the magnitude and kind of the foreign atoms in the grain boundaries.[17] Thus Hanson and Gaylor[18] found that magnesium greatly decreased the solubility of Mg_2Si in solid aluminum. This would result in greater quantities of material in the grain boundaries at the higher temperatures if the content of magnesium is increased with the other impurities remaining constant, and such an increase in the impurities in the grain boundaries may effectively act to hinder recrystallization to large crystals. This has been found to be true in the case of one of the commercially available strong wrought aluminum alloys with a magnesium content of about 1.5 per cent. Recrystallization studies of this latter alloy showed a decreased tendency to grow large crystals over the alloy whose recrystallization behavior is indicated in the diagram of Fig. 5.

Although the development of large grains is usually not desired and efforts are made to avoid them, it sometimes happens that recrystallization behavior may be made use of in other applications. Nadai[19] has suggested the possible use of recrystallization as an aid to stress determinations. In this case advantage is taken of the fact that for low deformations in the recrystallization diagram there is a relation between grain size and deformation that is easily observed on an etched specimen. Fig. 10 shows the striking similarity between the theoretically derived isochromatic lines, those obtained by photo-elastic methods, and the recrystallized structure of a specimen deformed according to the given conditions and then recrystallized. The exact degree of correspondence of such a recrystallization method has not been determined quantitatively as yet, and it is quite apparent from the shape of the recrystallization diagram that the applications are limited. However, even at the present time the recrystallization method offers an easy and approximate means of examining deformations occurring during drawing or forming operations.

[17] *See Reference 6, p. 353.*
[18] D. Hanson and M. L. Gayler, Jour. Inst. Metals, Vol. 26, p. 321, 1921.
[19] A. Nadai, *Plasticity*, p. 249, McGraw-Hill Book Company, New York, 1931.

Investigations of Velocity Fluctuations in a Turbulent Flow

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(Received July 8, 1935)

INTRODUCTION

THE investigations described in the present paper were concerned with a study of the mechanism of fully developed turbulent flow between straight parallel walls. The method used was that of the hot wire anemometer, whereby a fine electrically heated wire was introduced into the flow to be studied.

Defining u' as the instantaneous value of the component of velocity fluctuation in the direction of a parallel flow of mean velocity $\bar{u}$, and v' as the component of fluctuation normal to the flow, the present experiments consisted of measurements of root mean square values of u' and v', as well as the correlation between them. Fig. 1 represents a sample of such a fluctuation field where the origin 0 is taken for the condition $u = \bar{u}$, $v = 0$.

Reynolds,[1] in his theory of turbulent interchange, expresses the shearing stress arising from the momentum transport due to turbulence, in two-dimensional mean flow, as $\tau = -\rho\, \overline{u'\, v'}$. It is well known that for a fully developed parallel flow in a straight channel, the friction, τ, varies linearly from a value $(dp/dx)\ (b/2)$ at the wall, through zero at the channel center to $-(dp/dx)\ (b/2)$ at the other wall, where dp/dx is the pressure drop along the channel and b is the channel breadth. Hence the distribution of $\overline{u'\, v'}$ across the channel may be calculated directly from the pressure drop. Applying the principles of statistics to the fluctuation pattern illustrated in Fig. 1, we have that the correlation moment between u' and v' is given by $\overline{u'\, v'}$ while the scattering of u' is given by $(\overline{u'^2})^{\frac{1}{2}}$ and that of v' by $(\overline{v'^2})^{\frac{1}{2}}$, as discussed by Bateman.[2] The correlation coefficient is defined as $\overline{u'\, v'} / (\overline{u'^2})^{\frac{1}{2}}\ (\overline{v'^2})^{\frac{1}{2}}$. This factor is obtained by the present measurements in that $\overline{u'\, v'}$ is calculated from the pressure drop and values of $(\overline{u'^2})^{\frac{1}{2}}$ and $(\overline{v'^2})^{\frac{1}{2}}$ directly from the hot-wire measurements. Knowledge of the correlation factor is important for a full characterization of turbulent flow and reference is made to a paper by von Kármán[3] for further discussion of its significance.

APPARATUS FOR MEASUREMENT OF u'

The apparatus used for the measurement of u' has been described in detail in a paper by the author and A. M. Kuethe,[4] and will only be discussed briefly here.

The hot-wire for the u' measurements was about .015 millimeters in diameter and 3 millimeters long. It was mounted as shown in Fig. 2, with the axis of the wire parallel to the wall and perpendicular to the direction of mean flow. The distance of the wire from the wall was adjusted by means of a micrometer screw.

The u' hot wire was in one arm of a Wheatstone bridge circuit which could be balanced for each mean wind speed by means of a variable resistance box, R_1. Fig. 3 is a simplified schematic diagram showing in principle the circuit for both u' and v' measurements.

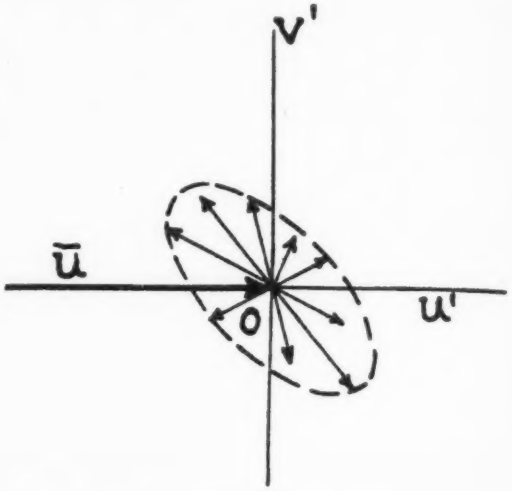

FIG. 1. Diagram of fluctuations.

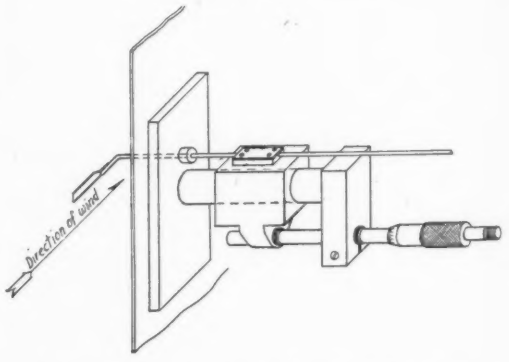

FIG. 2. u' anemometer with micrometer screw.

[1] O. Reynolds, *An Experimental Investigation of the Circumstances which Determine Whether the Motion of Water Shall be Direct or Sinuous and of the Law of Resistance in Parallel Channels*, Phil. Trans. Roy. Soc. 174, (1883).

[2] Dryden, Murnaghan, Bateman, *Hydrodynamics*, p. 369.

[3] Th. von Kármán, *Turbulence and Skin Friction*, Journal of the Aeronautical Sciences, Vol 1, No. 1, Jan. 1934.

[4] F. L. Wattendorf and A. M. Kuethe, *Investigations of Turbulent Flow By Means of the Hot-Wire Anemometer*, Physics, Vol. 5, June 1934.

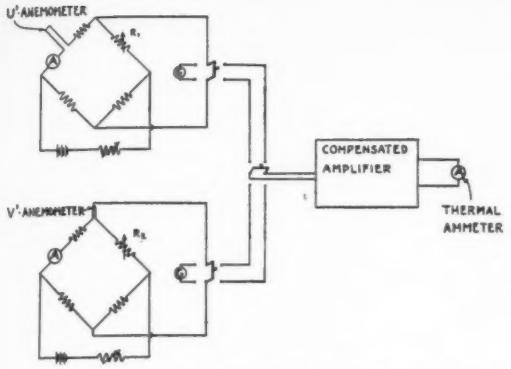

FIG. 3. Simplified diagram of hot-wire circuit.

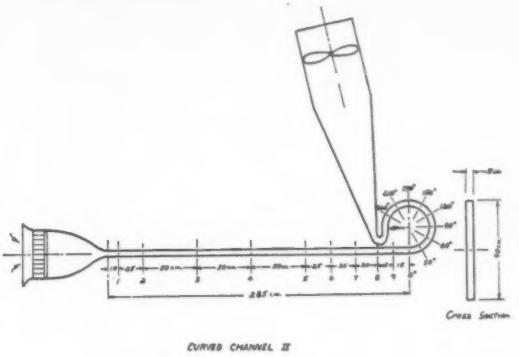

FIG. 4. Schematic diagram of channel.

After the bridge was balanced for a certain mean wind speed,[5] it was connected to a vacuum tube amplifier so that only the fluctuations in voltage about the mean value were amplified and measured. The amplifier was compensated for the thermal lag of the hot wire, so that the amplitude of response of the hot wire plus the amplifier was within 5% of a constant value over a range of frequencies between 50 and 500 cycles per second. Preliminary examination of oscillograms indicated that the main energy of the turbulent fluctuations was contained within the above mentioned range of frequencies.

The root mean square value of the output current of the amplifier was read directly on a thermal ammeter, which was calibrated in terms of the root mean square value of the velocity fluctuations. The wave shape could be recorded at any time by means of a string galvanometer oscillograph.

Apparatus for Measurement of v'

For the measurement of the component of velocity fluctuations perpendicular to the mean flow, a double wire of the Burgers[6] type was used. The present instrument was developed by A. M. Kuethe. The mounting was similar to that of the u' anemometer, except that there were two parallel wires spaced about .001 inch apart, with the plane common to both wires perpendicular to the mean flow, and with the wires parallel to the channel wall.

The two wires were connected in a Wheatstone bridge circuit as shown in Fig. 3. The variable slide wire resistance, R_2, in series with one of the v' wires, enabled the bridge to be balanced at zero angle of inclination, i.e. when the plane of the wires was perpendicular to the air stream. In this condition a change of direction of the air flow about an axis parallel to the two wires caused one wire to be partially shielded by the other, producing a change of resistance of one wire with respect to the other. This differential change of resistance between the wires caused a potential unbalance across the bridge, which was indicated by means of a galvanometer.

The calibration of the anemometer was made in a steady flow of known and constant direction, by rotating the instrument about an axis, parallel to the two wires and half way between them, through various angles, α, and recording the potential, b, across the bridge. The instrument was introduced into the turbulent flow to be investigated, and was adjusted so that there was zero mean potential across the bridge when the angle of inclination with the mean flow was zero. It was then connected to the compensated amplifier, and the root mean square values of the amplifier output voltage were read on the thermal meter as before. The output reading divided by the overall amplification factor gave the fluctuation of potential across the bridge, $(\overline{b^2})^{\frac{1}{2}}$. The corresponding root mean square angular fluctuation, $(\overline{\alpha^2})^{\frac{1}{2}}$, was read off the calibration curve of bridge potential versus angle. $(\overline{v'^2})^{\frac{1}{2}}$ was finally obtained as the product of the angular fluctuation and the mean velocity, i.e. $\bar{u}\,(\overline{\alpha^2})^{\frac{1}{2}}$.

The Channel

The channel in which most of the measurements were made was one previously used for research on curved flow. Fig. 4 is a schematic diagram of the channel. Only the straight portion of the channel was used for the present investigations.

The channel had a breadth of 5 centimeters and a depth of 90 centimeters which gave a ratio of depth to breadth of 18 to 1. This ratio was chosen large in order to obtain an approximately two-dimensional mean flow in the section at one-half of the channel depth. With the length of the straight section about sixty times the breadth, previous investigations showed that the

[5] The hot wire, being essentially unsensitive for direction changes, is balanced for the mean value of the absolute magnitude of the velocity vector; the fluctuations observed are approximately equal to the fluctuations of the u-component; the v' and w' fluctuations entering with a higher order.

[6] J. M. Burgers, *Proc. Acad. Amsterdam*, 39, 1935.

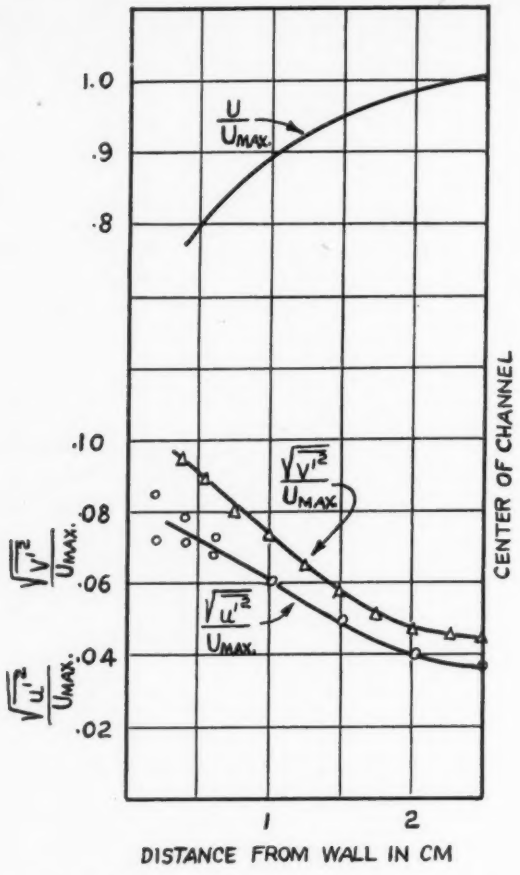

FIG. 5. Distribution of $(\overline{u'^2})^{\frac{1}{2}}/u_{\max}$ and $(\overline{v'^2})^{\frac{1}{2}}/u_{\max}$

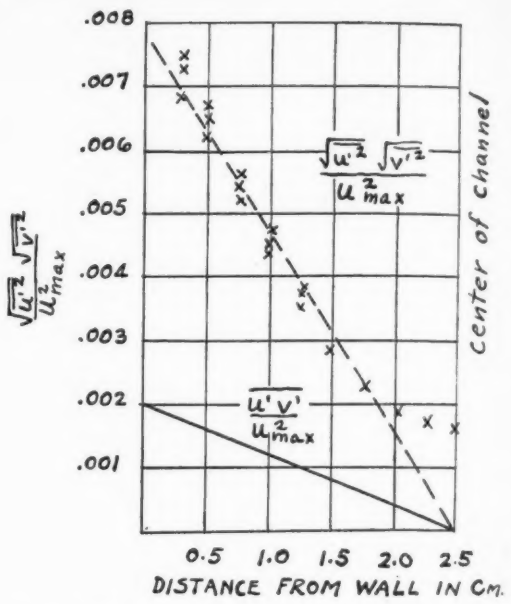

FIG. 6. Distribution of the product of $(\overline{u'^2})^{\frac{1}{2}}/u_{\max}$ and $(\overline{v'^2})^{\frac{1}{2}}/u_{\max}$

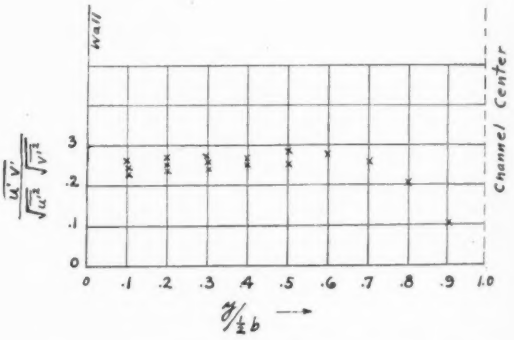

FIG. 7. Correlation between u' and v' velocity fluctuations.

flow was in a fully developed turbulent state at measuring stations 8 and 9.

The hot-wire was projected through a hole in the channel wall at the measuring station, and moved through the channel by means of the micrometer screw shown in Fig. 2.

MEASUREMENTS

The hot wire measurements were taken at stations 8 and 9 of the straight channel, where the flow was in a fully developed state. Fig. 5 shows the distribution of $(\overline{u'^2})^{\frac{1}{2}}$ and $(\overline{v'^2})^{\frac{1}{2}}$ over one-half of the channel at the stations mentioned. The u' measurements have been discussed in reference 4, while the v' measurements were made more recently by the author and Dr. Charles Sadron, and should be considered of a preliminary nature. It may be said that the shape of the curve is thought reliable although the level is not considered accurate.

Fig. 6 shows the distribution of the product of $(\overline{u'^2})^{\frac{1}{2}}$ and $(\overline{v'^2})^{\frac{1}{2}}$ across one-half of the channel, as well as the distribution of $\tau/\rho = -\overline{u'v'}$ as calculated from the pressure drop. The significant thing is that the distribution of $(\overline{u'^2})^{\frac{1}{2}}$ $(\overline{v'^2})^{\frac{1}{2}}$ is not far from linear except in the neighborhood of the wall and channel center. This would indicate a fairly constant correlation factor over the major portion of the channel. The correlation factor $\overline{u'v'}/(\overline{u'^2})^{\frac{1}{2}}$ $(\overline{v'^2})^{\frac{1}{2}}$ is shown in Fig. 7, and it is seen to be not far from constant, except near the center, where of course it must go to zero, since the friction, τ, passes through zero at the center.

This result may be considered as furnishing experimental evidence that the assumption of similarity of the turbulence mechanism as proposed by von Kármán,[7] is not far from reality in the case of parallel turbulent flow.

[7] Th. von Kármán, *Mechanische Ahnlichkeit und Turbulenz*, Nachr. Ges. Wiss., Göttingen, 1930.

Tests on Ventilation Openings for Aircraft

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(Received December 7, 1935)

AIRSHIPS must be provided with effective openings for the intake and discharge of air and lifting gas for various purposes. The scoops and hoods covering the openings must be designed so that they accomplish the desired movement of air, or at least contribute to the ventilating action of other installations of the duct. Insofar as they can offer an appreciable resistance in flight, their aerodynamic effect merits careful study. A number of different forms were therefore tested in the wind tunnel of the Daniel Guggenheim Airship Institute in such a way that all characteristic elements were measured, namely the drag and the flight velocity, the air delivery, and the built-up pressure.

The tests were arranged mainly from the point of view of requirements for airship use, where the ventilation question is of particular importance.[1] They are of course also applicable to other aircraft, surface ships, etc. A need for such tests seemed to exist, particularly since other scoop tests known to the authors do not take into consideration all of the characteristics of the scoops.[2, 3, 4]

The great variety of scoop forms which are in practical use made it impossible to cover all the characteristic types of ventilation openings in as complete a manner as desirable. The test results presented in this report should only indicate various possibilities and factors affecting efficient ventilation.

Test Set-Up

The tests were conducted in the 6.5 ft. vertical wind tunnel of the Daniel Guggenheim Airship Institute.[5] A vertical wooden plate, representing a section of the outside of an airship hull, was placed 5 inches off center of the air stream. The plate extended across the air stream and into the jet entrance diffusor with a lip of about 6 inches. About 1.5 ft. above the jet entrance a 4 ft. square section was cut away from this plate. With no scoop attached, the boundary layer of the plate at this point was about ¾″ thick at 20 m./sec. In this opening was fitted a sheet-metal chamber, the front face of which was flush with the remaining portion of the wooden plate. The various scoops and the air outlet openings were attached to this front face (see Fig. 1). The chamber could move freely within the wooden plate, and was held in position through four supports resting on hydraulic balances. A blower was connected to the rear portion of this floating chamber by means of suitable piping, which was used for changing the delivery of air beyond the natural action of the scoops. The portion of the piping in the air stream and all supports were completely shielded by a sheet-metal guard, reducing the tare drag to the small amount of the surface friction on the front face of the floating chamber. The drag of the ventilation opening measured thus need be corrected only for the pressure due to the air flowing inside of the elbow in the pipe leading from the floating chamber to the water lock. The built-up pressure was determined by suitable pressure holes around the openings in the front face of the floating chamber. The air delivery was measured by means of an orifice in the pipe between the water lock and the blower. The blower, due to its limited size, was mainly responsible for the dimensions of the opening and the relatively low flight speed (i.e. low wind tunnel speed) which was chosen so as to give a wide pressure range in determining the characteristics for each scoop.

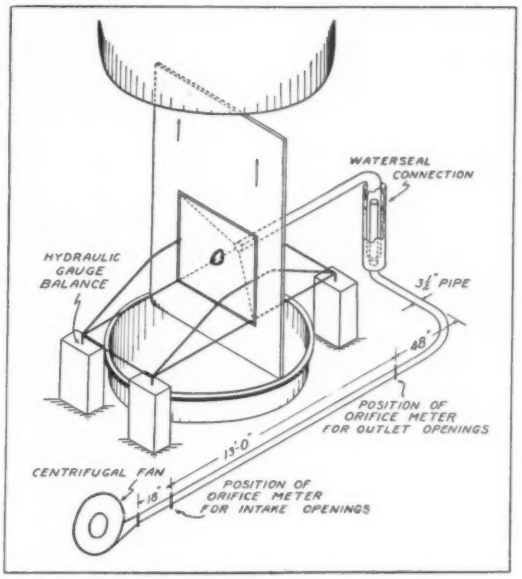

Fig. 1. Test set-up in wind-tunnel.

[1] Th. Troller, *Aerodynamic Research at the Daniel Guggenheim Airship Institute,* Daniel Guggenheim Airship Institute Publication No. 3.

[2] H. F. Schmidt, *Theoretical and Experimental Study of Condenser Scoops,* Journal of the American Society of Naval Engineers, February 1930.

[3] H. J. Hanslik, *Condenser Scoops in Marine Installations,* J. of the Am. Soc. of Nav. Eng., May 1931.

[4] H. F. Schmidt and O. L. Cox, *Test on a One-Quarter Scale Model Scoop,* J. of the Am. Soc. of Nav. Eng., August 1931.

[5] Th. Troller, *The Wind Tunnel of the Daniel Guggenheim Airship Institute,* Daniel Guggenheim Airship Institute Publication No. 1.

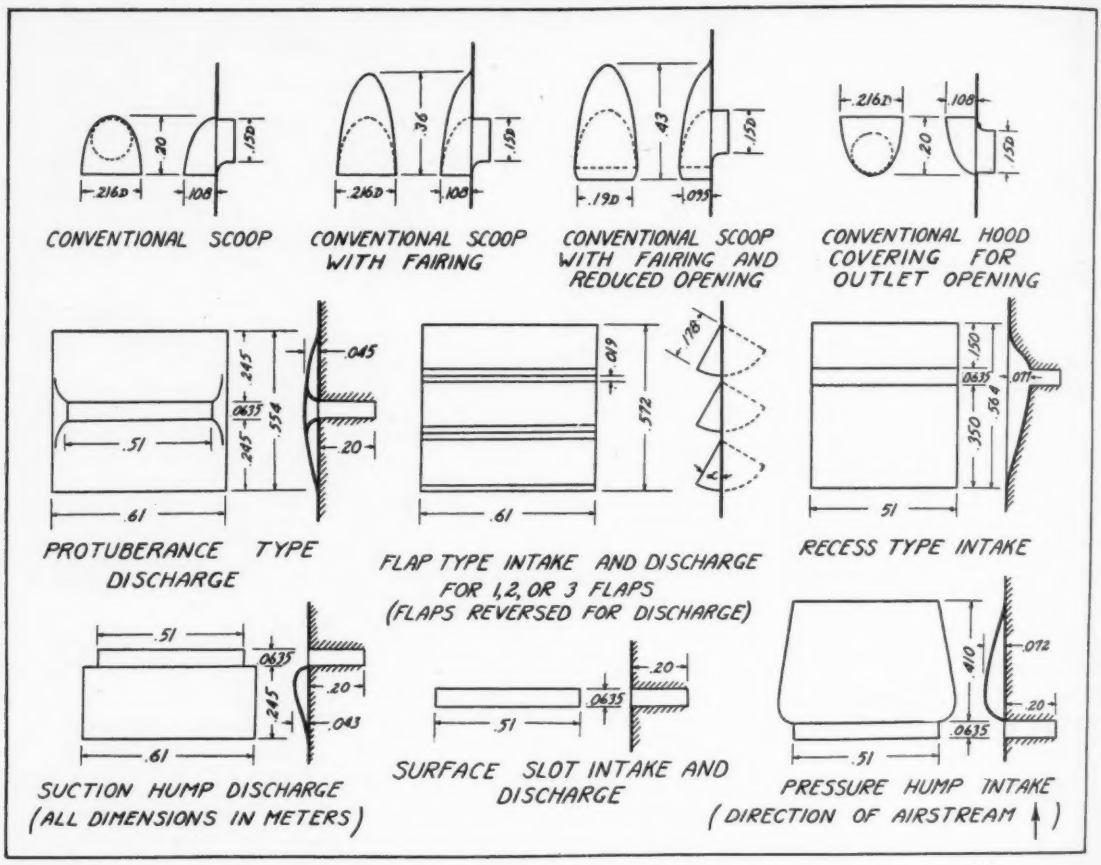
CONVENTIONAL SCOOP
CONVENTIONAL SCOOP WITH FAIRING
CONVENTIONAL SCOOP WITH FAIRING AND REDUCED OPENING
CONVENTIONAL HOOD COVERING FOR OUTLET OPENING
PROTUBERANCE TYPE DISCHARGE
FLAP TYPE INTAKE AND DISCHARGE FOR 1,2, OR 3 FLAPS (FLAPS REVERSED FOR DISCHARGE)
RECESS TYPE INTAKE
SUCTION HUMP DISCHARGE (ALL DIMENSIONS IN METERS)
SURFACE SLOT INTAKE AND DISCHARGE
PRESSURE HUMP INTAKE (DIRECTION OF AIRSTREAM)

FIG. 2.

TEST METHOD

The wind velocity, drag of the ventilation openings, air delivered, and built-up pressure were measured. The three latter characteristic values, as functions of the velocity and as functions of each other, are in themselves interesting. They are summed up in a dimensionless coefficient which we call the efficiency. This coefficient is defined

$$E = \frac{Q\,\Delta p}{Dv - Qq} \text{ for air intake,}$$

$$E = \frac{Q\,(-\Delta p)}{Dv + Qq} \text{ for air discharge.}$$

The over-all efficiency of a ventilation duct in which the movement of air is entirely due to the action of the scoops is then characterized by:

$$E_{\text{total}} = \frac{Q\,(\Delta p_{\text{intake}} - \Delta p_{\text{discharge}})}{(D_{\text{intake}} + D_{\text{discharge}})\,v}$$

where

Q = delivered air volume per unit time,
Δp = pressure difference between free air and immediately inside opening,
D = drag of scoop or discharge,
v = flight velocity,
$q = \rho/2\ v^2$, ρ = density of air.

This coefficient permits a comparison of the scoop action with that of ventilation blowers.

The numerator in each of the expressions for the efficiency represents the power output, the useful work, as in the definition for blower efficiencies (the dynamic air pressure inside the chamber at the pressure openings is negligible); the denominator represents the power input. The first term of the denominator is equivalent to the energy delivered on the shaft to the rotor of a blower or to the blades of a propeller; the second term corresponds to the effect of the slip on the propeller, more specifically to the effect of the circumferential component of the induced velocity on a propeller. It is introduced in the terms under consideration by the relative movement of the aircraft to the surrounding air. The energy available for the delivery of air against the inside pressure is then diminished—or increased—by the kinetic energy Qq, which must necessarily be imparted first to the air in taking it into the moving aircraft. E_{total} is the quotient resulting from dividing total gained work by total power input.

TEST RESULTS

Some characteristic forms tested in the wind tunnel are shown in Fig. 2. The "conventional" type is one

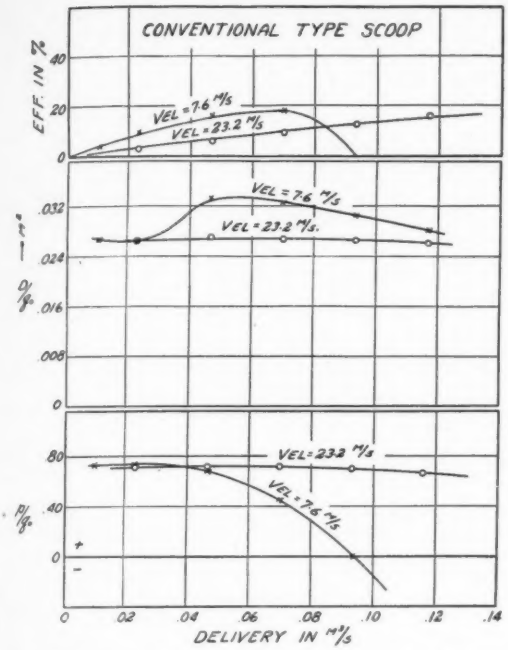

FIG. 3. Efficiency, drag-area, and built-up pressure of a conventional scoop, as a function of deliveries at various air speeds.

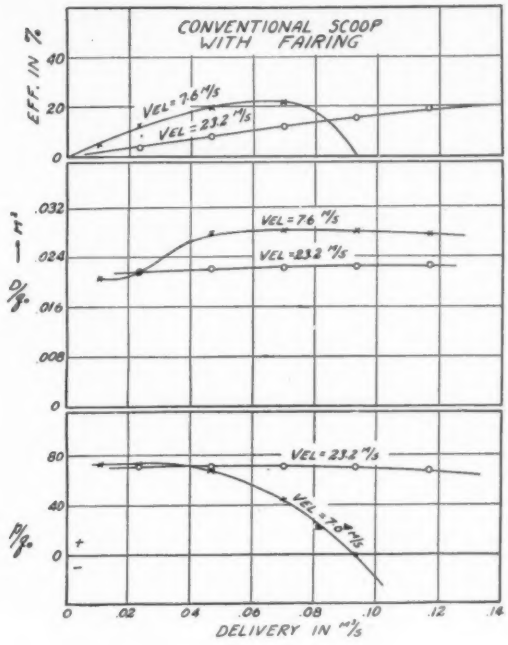

FIG. 4.

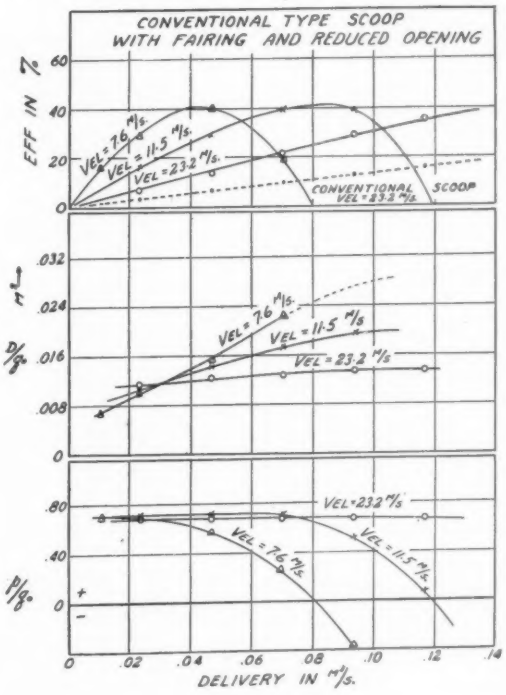

FIG. 5.

form that has been in actual use on airships. The characteristics shown in Fig. 3 are self-explanatory, as are also the tests with the same scoop with streamline fairing and with reduced entrance (Figs. 4 and 5). The built-up pressure is not affected for small deliveries, but falls off rather rapidly after a certain critical value has been reached. The efficiency has a rather sharp peak, indicating that a proper scoop should be determined carefully, whenever prevailing conditions are considered. The sudden jump of the drag value in the scoop characteristics shown in Figs. 3 and 4 is obviously an effect of the entrance lip of the scoop. It merits further investigation, but was realized too late during the testing procedure to be included in this report. The character of this rise in drag with increasing deliveries is quite different after the change of the entrance (see Fig. 5). The "conventional with fairing and reduced opening" scoop is obviously superior in its efficiency to the "conventional" scoop.

In Fig. 6 the characteristics of a flap-type scoop are given. This scoop is very convenient when variable delivery or pressure is desired. However, its efficiency is so low that other designs with suitable regulation should prove superior from the viewpoint of aerodynamic efficiency. An opening over about 45° will in no case bring any advantage for pressure or delivery. Also the arrangement of several flaps, at least if they are placed at short distances behind each other, decreases the desired action (see Fig. 7).

Fig. 8 shows the characteristics of the "recess-type" scoop. This scoop makes use of the fact that an increase in static pressure occurs with the widening of the streamlines and the slower air velocities near the opening in the recess. The efficiency of such an intake is far superior to any other scoop on which tests were made. The built-up pressure is lower than at the "con-

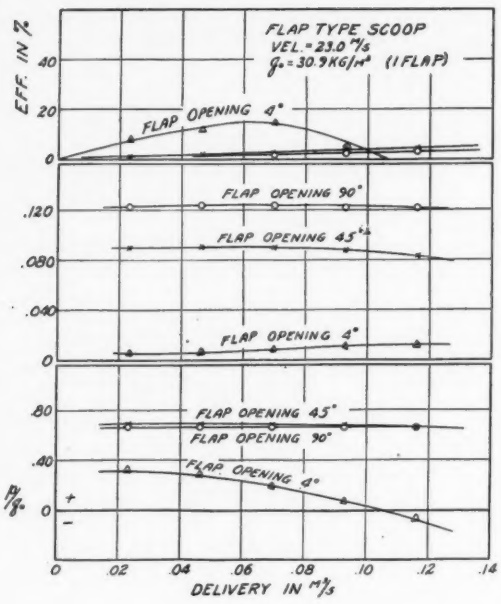

FIG. 6.

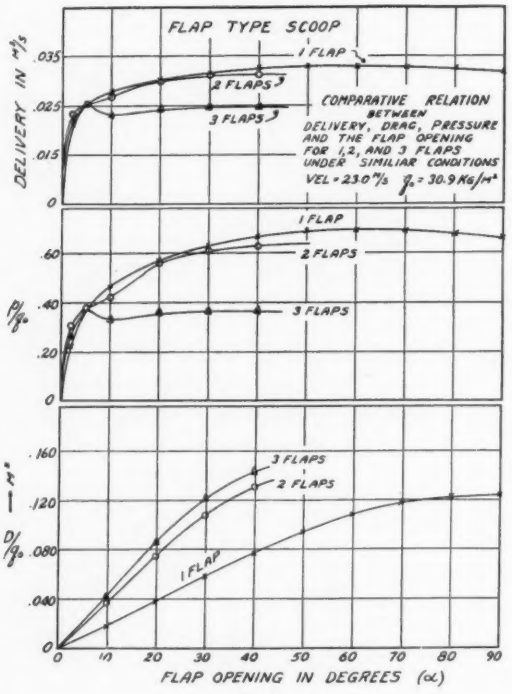

FIG. 7.

ventional" scoop. However, it may be pointed out that at a built-up pressure of about $p/q = 0.35$, the recess type scoop gives efficiencies of 40 to 60 per cent, higher than the maximum shown in Fig. 5, and well above the 20 per cent of the "conventional" scoop. The "recess-type" seems to have possibilities of further improvement, which should be carefully considered. The

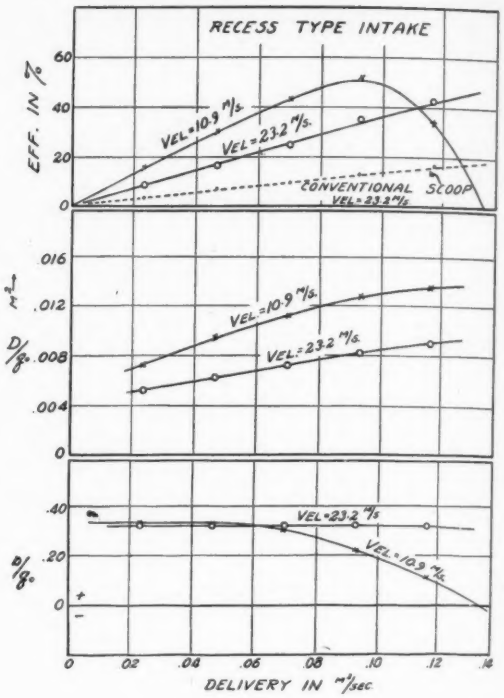

FIG. 8.

'recess-type" intake shows a marked dependence on the Reynolds number, or rather, on the thickness of the boundary layer of the wall, as might be expected. Of the various other means for intake of air, which were tested, none proved efficient. For example, the pressure hump (see Fig. 2) has a maximum efficiency of 20 per cent at $p/q = 0.4$.

The ideal air discharge would be one throwing the air out and to the rear. If the discharge velocity were equal to the flight velocity of the aircraft, the discharged air would not retain any kinetic energy. The drag of the discharge mechanism should then be negative, being a reaction. It is of course hardly possible that this condition be accomplished without some kind of blower.

Figs. 9 and 10 show the characteristics of some of the discharges investigated. The "protuberance-type" discharge (see Fig. 2) shows a maximum efficiency of about 5 per cent at $p/q = -0.1$; the "suction hump", a maximum efficiency of about 10 per cent at $p/q = -0.2$. The efficiency of the suction hump and the built-up pressure changed very little over a great range of deliveries.

In general, it can be seen that the efficiency is poor. The fact that there is no discharge available which even approaches the favorable condition, is a decided drawback for the efficiency of any ventilation system depending only on the effect of the intake and discharge openings for its action. For this reason, ventilation by means of a blower will very often have to be considered efficient enough to justify the additional weight and

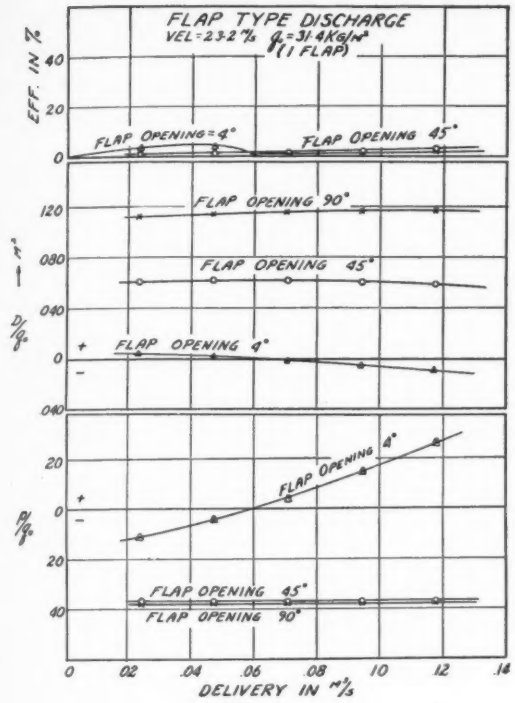

FIG. 9.

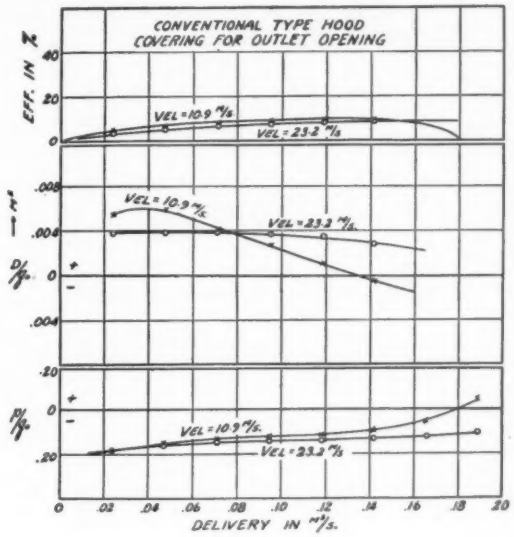

FIG. 10.

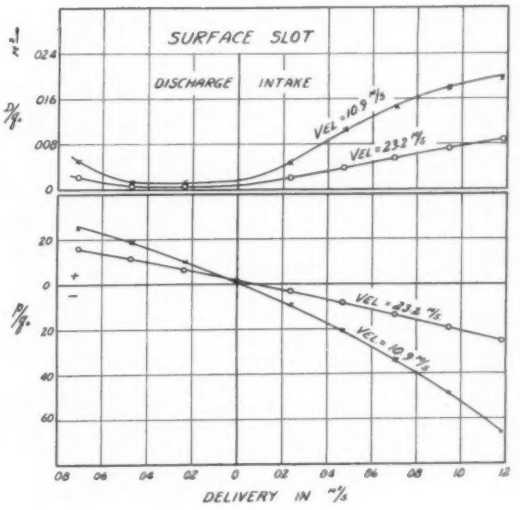

FIG. 11.

complication of such a blower. Fig. 11 shows drag and pressure of a slot when air is discharged or taken in. A qualitative study of discharges of this type is to be found in Reference 2.

RÉSUMÉ

For the application of the results of the test series presented here, it must be taken into consideration that the local speed in the vicinity of the ventilation attachment forms the basis to which the given characteristics refer, and that the boundary layer thickness will have an important influence on the local conditions. Furthermore, it is necessary to multiply the scoop efficiency by the propeller efficiency to obtain a comparison between the efficiency of scoops and that of blowers or fans. Assuming an average propeller efficiency of 75 per cent, and, from the above test results, an average efficiency of the scoop proper of 40 per cent, we can expect an over-all efficiency for scoop-type ventilation, of $E = 0.4 \times 0.75 = 0.3$.

Assuming that the discharge openings were the same for the blower ventilation and for the scoop ventilation system, we must still consider the difference in weight of the two installations for a proper comparison of the two systems. A good blower has an efficiency of about $E_b = 0.8$. In general, the scoop weight may be considered negligible.

The additional weight of the blower installation W_b will require for its transportation on an airplane in level flight

$$N_{TB} = W_b \frac{C_D}{C_L} v \frac{1}{E_{\text{prop.}}},$$

where C_D and C_L are the drag and lift coefficients of the airplane at the flight conditions considered; $E_{prop.}$ is the propeller efficiency. In an airship the required N_{TB} is given as $N_{TB} = W_b \, w_{\text{vol.}}^{\frac{2}{3}} \, C_{D\text{vol.}} \, v \frac{1}{E_{\text{prop.}}}$, where $w_{\text{vol.}}$ is the necessary airship volume per weight unit carried and $C_{D\text{vol.}}$ the drag coefficient $\frac{D}{q \, \text{vol.}^{\frac{2}{3}}}$. This power N_{TB} must be added to the power input of the blower in the computation of the total ventilation power requirement of an aircraft.

For example, a 3 hp. blower installation weighing 75 lbs. would require $N_{TB} = 3.7$ hp. if carried on an airplane flying at 200 m.p.h. in level flight, at $C_D/C_L = 0.06$ and $E_{prop.} = 0.75$; for the same blower installation on an airship flying at about 80 m.p.h., where $W_{vol.} = 1/15$ lbs. per cu. ft., $C_{D\,hull} = 0.014$, $E_{prop.} = 0.75$, the transportation power is $N_{TB} = 0.3$ hp. The over-all efficiency for the ventilation by means of a blower is then:

$$E_o = 0.8\ \frac{3}{3+3.7} = 0.36 \text{ for the airplane; and}$$

$$E_o = 0.8\ \frac{3}{3+0.3} = 0.73 \text{ for the airship.}$$

The blower weights, chosen arbitrarily in this computation, are rather low. Furthermore, the conditions are even more favorable for the scoop in climbing than in level flight. Accordingly, scoops seem to be indicated for the airplane considered, whereas the blower would appear far superior on the airship.

The tests described in this report are by no means sufficient to cover the problem completely. They give a basis for the planning of ventilation systems for aircraft, and in the more important cases, the best form should be determined by special wind tunnel tests.

Book Reviews

Aerodynamic Theory, W. F. DURAND, Editor-in-Chief; Vol. V, Julius Springer, Berlin, 1935. Divisions N and O. Cloth, 6 x 9 in., XVIII plus 347 pages, special price until publication of last volume, rm. 20.

The subjects of Dynamics of the Airplane and Airplane Performance are dealt with in the fifth volume of the series on "Aerodynamic Theory." The division on dynamics is by B. Melvill Jones and that on Performance by L. B. Kerber.

In the section on dynamics, Professor Jones does an excellent job of stating the present position of the science in this field. This is to be expected from a consideration of the author's wide experience in the subject. As must necessarily be the case, the methods given are essentially those of Bryan and Bairstow. However, the use of non-dimensional coefficients greatly clarifies the calculations which are further simplified by the clearly stated derivations of these coefficients.

This section can be divided into two parts according to mathematical complexity, the first four chapters being relatively elementary. The subject matter dealt with in these chapters includes the following: steady motion, the determination of pitching, rolling and yawing moments, and an introductory discussion of airplane motion. This part of the section is recommended to undergraduate engineering students.

The work covered in the remaining chapters requires a better mathematical background than the average undergraduate can furnish. These chapters deal with the derivation of the equations of lateral and longitudinal motion and their numerical solutions. In addition, a discussion of the spin is included.

This reviewer agrees with the author in his expressed fear that the methods advocated will not be applied to airplane design in the near future. In fact, these same methods have been available to the airplane designer in a more cumbersome form since the early days of flying, and although there are more data available now to simplify the calculation of the airplane coefficients, there is no reason to believe that the objections to the method have been removed.

The chief of these objections is not the mathematical difficulty of the work involved, but the fact that the more laborious method of stability calculation is not justified in the light of the results obtained. After all, what is the use of calculating the period and damping of a given motion if the designer has not got the slightest idea of what the period and damping should be for optimum results. Moreover, the evaluation of the flying characteristics is usually left to the pilot who, in general, is not concerned with the natural motion of an airplane; the controlled motion is of much more interest to him. That pilots prefer the flying characteristics of an unstable airplane is a common experience.

Consequently, this reviewer believes that stability computations will become more complicated before they are used by aeronautical engineers. And these computations will deal entirely with controlled motion. However, before this can be done, the designer will require additional experimental information regarding the average reactions of pilots to certain standard motions. When these computations are made, this division of "Aerodynamic Theory" will provide an excellent basis.

The division on "Airplane Performance" by Kerber, includes the common methods of estimating the required and available horsepower from which the airplane performance may be computed. The aeronautical engineering student will find this a convenient reference to the general methods that have been used in this field.

O. C. KOPPEN

Squadrons of the Royal Air Force, by MAJOR F. A. DE V. ROBERTSON, LIEUTENANT COMMANDER C. N. COLSON, AND FLYING OFFICER W. A. COOK; Flight Publishing Co. Ltd., London, 1936; 130 pages, 7s, 6d.

During the past six years *Flight* has published a series of articles on individual squadrons and other units of the Royal Air Force. These have now been made into a book which, with excellent pictures, gives a graphic account of the work of an air force in peace as well as war. A brief history of the beginnings of the use of aeronautics by British fighting services from the days when balloons were used in 1878 by the Royal Engineers gives a background which is helpful in understanding how the Royal Air Force was formed. Chapters on the Central Flying School, the R. A. F. Staff College, the School of Technical Training, the Auxiliary Air Force and the University Air Squadrons give excellent accounts of the Training units.

The book is not only of interest to those who served with the British during the World War but to all students of military and naval aviation.

Tests on the Stress Distribution in Reinforced Panels

ROLAND J. WHITE, *Curtiss-Wright Airplane Company*
HANS M. ANTZ, *California Institute of Technology*

(Received September 30, 1935)

Note. This paper describes an exploration into the field of "shear-lag," or the tendency of stresses in the covering of stressed-skin structures to be concentrated near certain stiffeners and to be very small near others. In this case the loads are applied to the edge stiffeners at one end of the test panel and a procedure is developed for determining the loads carried by the intermediate stiffeners.

As it stands, the method is partly rational and partly empirical, since the determination of the coefficients p and A_n depends on test data. The agreement between computed and observed values indicates that the method is well founded and that further work should be done to perfect the process so that designers may have a method for circumventing the difficulties of "shear-lag" and non-uniform stress distribution in stiffened structures. By publishing the paper here it is hoped to provoke further testing and research along these lines. *The Editor.*

INTRODUCTION

IT is common practice in metal aircraft construction to use thin metal panels reinforced with longitudinal stiffeners which are restrained from buckling by the metal sheet and bulkheads. Panels of this type may be subjected to various applied loads and a knowledge of how these loads are distributed throughout the panel is necessary if efficient structures are to be designed. The authors first became interested in this problem when Dr. A. L. Klein of the California Institute of Technology suggested that a careful study of the best arrangement of material in a stressed skin airplane wing should be made. Before such a study could be attempted a more precise knowledge of the stress distribution in thin sheet reinforced panels seemed necessary, which resulted in the present investigation. Tests were made on two reinforced panels subjected to a very simple load condition in order to study how the applied loads were transferred to the various stiffeners.

A POSSIBLE DESIGN METHOD

This method assumes the stiffened panel to be replaced by a system of columns equal to the number of longitudinal stiffeners in the panel and each having a cross-sectional area equal to that of the stiffener plus a portion of the adjacent sheet. These columns are then subjected to the external applied axial loads, which may be either concentrated or distributed along the column, and the distributed axial loads introduced by the shear action of the sheet. Introducing an assumption as to how the shear load is transferred serves to inter-connect this system of columns to form a complete structure. This was accomplished by assuming the shear load transferred to be proportional to the difference of deflection of the adjacent columns at the point of transfer of the load. If τ_n is the load per unit length along the column transferred from the $n-1$ to the n *th* column then by the above assumption,

$$\tau_n = \eta G t/h \times (y_{n-1} - y_n) \qquad (1)$$

where

y_n = axial deflection of the n *th* column.
t = thickness of sheet.
h = distance between columns.
G = Shear Modulus of the sheet material.
η = empirical constant.

The value of η, together with an estimate of the area of sheet to include with that of the stiffener, are the two empirical quantities which must be determined by experiment. If the shear deformation occurred without the sheet buckling and all stiffeners were rigidly restrained against any tranverse deformations the value of η should be equal to 1.00, on the other hand if a diagonal tension field is formed η would be reduced to about 0.625 for dural or steel.[1]

Writing the equation for the equilibrium of axial forces on an element of the n *th* column and remembering that unit strain is dy_n/dx where x is the coordinate along the axis of the column; the following differential equation expresses the deflection of the n *th* column:

$$(d^2y_n/dx^2) - k_n(-y_{n-1} + 2y_n - y_{n+1}) = w_n/A_nE \qquad (2)$$

where

$k_n = \eta t G/A_n h E$
w_n = axial distributed applied load on the n *th* stiffener.
A_n = effective area of cross-section of the n *th* stiffener.
E = Young's Modulus.

In order to determine the axial deformations, and hence the stress distribution, it is necessary to solve simultaneously a system of such equations equal in number to the number of stiffeners in the panel. The solution of these equations becomes very difficult as the number of stiffeners increases, which makes their practical application impossible; except perhaps for some very special load conditions. It should be noted that these equations are similar to those obtained for the classical problem of the vibration of a weightless string loaded with equally spaced masses except that the frequency

[1] Paul Kuhn, *Analysis of 2-Spar Cantilever Wings With Special Reference to Torsion and Load Transference*, N.A.C.A. Report No. 508.

TABLE I

Specimen	No. 1	No. 2
Length of panel.....	48 in.	48 in.
Number of stiffeners..	3	7
Distance between stiffeners.....	6.00 in.	4.00 in.
Area of one center stiffener (no sheet included).....	2 x .044 sq. in.	2 x .044 sq. in.
Area of one edge stiffener (no sheet included).....	2 x .090 sq. in.	2 x .090 sq. in.
Total area of cross-section (including sheet).....	.748 sq. in.	1.40 sq. in.

of vibration in this case is imaginary, and hence their solutions are in terms of hyperbolic instead of trigonometric functions.

From strain measurements on test panels dy_n/dx is determined as a function of x. By graphical integration and differentiation y_n and d^2y_n/dx^2 may be determined. These values, when substituted in Eq. (2), will enable k_n to be determined for each stiffener as a function of x. This is a possible parameter that may be used in evaluating future test data as it is a measure of the ratio of shear to compression rigidity.

The authors were able to obtain a solution of these equations for a three stiffener panel having a uniform support across the base and subjected to compression loads applied to the edge stiffeners at the opposite end of the panel. This solution, based upon the assumption that the effective area of the edge stiffener is twice that of the center stiffener, is

$$\left.\begin{aligned} S_A &= \frac{2P}{A_T}\left[\frac{\cosh px - \tanh pL \sinh px}{4} + 1\right] \\ S_B &= \frac{2P}{A_T}[-\cosh px + \tanh pL \sinh px + 1] \end{aligned}\right\} \quad (3)$$

$$p^2 = \frac{25}{2}\frac{\eta t G}{A_T h E}$$

Here S_A is the stress in the edge stiffeners and S_B that of the center stiffener. The origin of the x axis is taken at the end of the panel on which the concentrated loads P are applied. The length of the panel is denoted by L and A_T is the effective cross-sectional area of all three stiffeners. Lack of space prevents giving the intermediate steps in obtaining this solution.

DESCRIPTION OF TESTS

The specimens tested consisted of two rectangular panels one having three longitudinal stiffeners and the other seven. These were furnished through the courtesy of the Douglas Aircraft Corp. and were made of 24–S T Alclad sheet reinforced with extruded bulb angles. Both panels were fabricated with $\frac{3}{32}$ in. rivets spaced at one inch. The stiffeners were composed of two bulb angles riveted together on opposite sides of the sheet making the combination symmetrical about the plane of the sheet. While this is not a common occurrence in practice it helped to prevent any lateral deformation of the stiffeners which was desired, as stresses due to axial deformations only were of interest. The stiffeners which formed the sides of the panels had approximately twice the area of the center stiffeners. The dimensions of both specimens are given in Table I. The base of the panels was carefully filed so as to obtain a uniform support across the base which rested on a milled surface. Concentrated loads were applied symmetrically to the upper ends of the edge stiffeners, which were reinforced locally and extended ½ in. beyond any of the center stiffeners. (Fig. 1.) The panels were restrained both laterally and transversely by iron angles spaced at 12 in. intervals and were free to slide on two vertical metal strips held rigidly in the test machine. Clips from the iron angles prevented any lateral deflection of the center stiffeners but did not restrain them axially. Loads were applied by means of a hydraulic jack and two Ames dial gages attached to the metal strips enabled a symmetrical loading to be obtained. The stresses were measured by four Huggenberger extensometers. The jack loads were applied in 1000 lb. increments until a load of

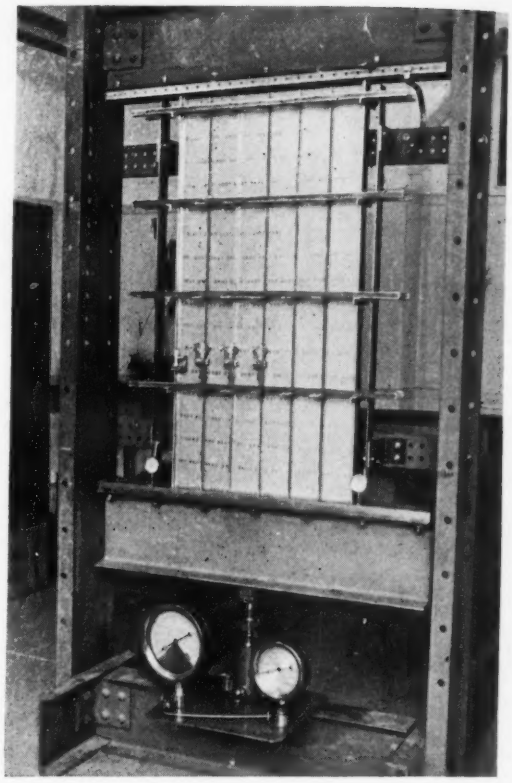

FIG. 1. Specimen No. 2 in Test Machine.

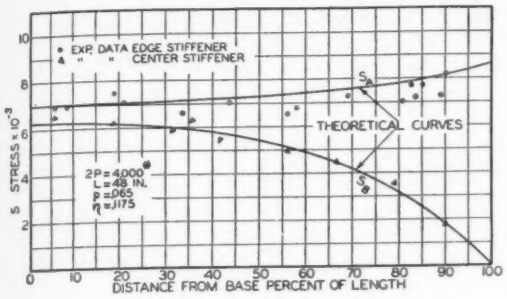

FIG. 2. Experimental Results—Specimen No. 1.

7000 lb. was obtained. Readings were taken both during the loading and unloading of the jack. The extensometers were then moved and the process repeated. In all cases the stresses were measured on the inside face of the bulb angle which was riveted to the sheet.

RESULTS OF TESTS

The stress measurements of specimen No. 1 are plotted in Fig. 2. Superimposed on these data are the theoretical curves calculated from Eqs. (3). The evaluation of p and A_T were determined from the stress measurements at the base of the panel. Taking $S_A = 7.00 \times 10^3$ and $S_B = 6.30 \times 10^3$ at $X = L = 48$ in. the value of $p = 0.065$ was determined. Using $E = 10 \times 10^6$ and $G = 4 \times 10^6$ a value of $\eta = 0.1175$ was calculated. Estimating the mean stress to be 6.89×10^3 for $2P = 4{,}000$ lb. A_T was found to be 0.580 sq. in.

A very reasonable agreement is obtained between the measured and calculated stresses for this three stiffener panel. The calculations are based on the assumption that the effective area of the edge stiffener is twice that of the center; however, an estimate of effective area ratio of 1.75 or 1.80 is believed to be more reasonable. Better agreement should be expected if Eqs. (3) were rederived on this basis.

The test data for specimen No. 2. are plotted in Fig. 3. The stresses are expressed in ratio form in terms of S_M where

$$S_M = 2P/\text{Total cross-section area of panel}$$

The fact that the stress ratio is greater than 1.00 at the base of the panel indicates that the stress distribution is not uniform across the bottom; i.e. a portion of the sheet must be considered as ineffective in carrying stress. The stress ratios have been calculated for different values of the applied load and indicate (within the precision of measurement) that the stress distribution did not change for different applied loads. The stress measurements for the edge stiffener in both panels have an appreciable experimental scatter. This is believed to be due to difficulty in obtaining a satisfactory extensometer mounting. Under load a warping

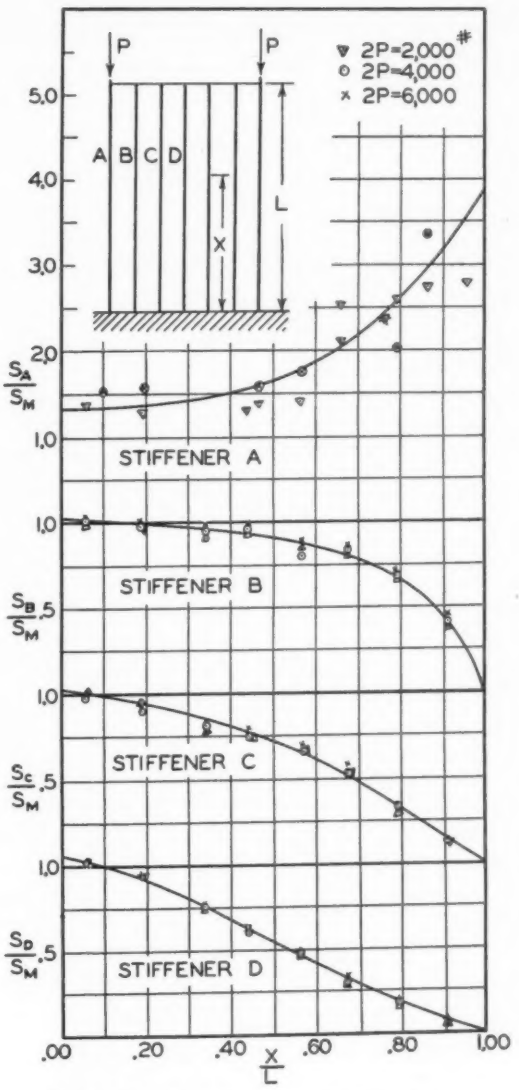

FIG. 3. Experimental Results—Specimen No. 2.

of the edge stiffener could be detected which probably effected the stress measurements of this stiffener.

DISCUSSIONS

The proposed method of design is approximate in several respects.

(1) It has been assumed that an element of shear load is transferred directly across to the adjacent stiffener. For a tension field we know that the load is transferred along a line at about 45 degrees.

(2) The effective area of sheet to include with the area of the stiffener along with η may be expected to vary along the length of the panel; however, the value of k_n which must be estimated depends upon the ratio of these quantities, hence these effects may

counteract each other to a certain extent. When the sheet buckles causing a decrease in η the effective area A_n should also be reduced.

(3) It is assumed that the deformation of the sheet between any two stiffeners is independent of that between any two other stiffeners, hence for a thick sheet combined with light stiffeners this method of analysis should not be applicable. It has been assumed that all of these effects can be approximated by a single value of k_n which can be estimated when η and A_n are specified.

The value of $\eta = 0.1175$ as determined from specimen No. 1. came out lower than expected. Most of the load was transferred as a tension field in the upper quarter of the panel, which would indicate a value of $\eta \cong 0.625$; however, it is believed that the free end of the sheet along with the fact that the stiffeners were not rigidly restrained in a transverse direction caused this low value of η. This may also be inherently low due to approximations in the method.

If further tests can be made to substantiate the proposed principle of design the application of the energy method may offer a means of simplifying the calculations, as has been done in the case of numerous vibration problems. Possibly a numerical means of proportioning the applied loads similar to the Hardy Cross method, which is used in distributing bending moments in redundant frame structures, may be developed. At present there is a need for tests on very long panels subjected to distributed side loads which simulates the flange material included between the webs of a stressed skin metal wing. In actual design curved panels having tapered and discontinuous stringers occur which further complicates the problem. The method presented here is basic in its concept and it is hoped that further work will be done along this line.

Book Reviews

Diesel Aircraft Engines, edited and published by PAUL H. WILKINSON, 160 Jay St., Brooklyn, N. Y., 1936; 157 pages, $3.50.

For many years the potential advantages of the compression ignition engine for certain kinds of aircraft operation have been recognized. Mr. Wilkinson has rendered a service to all interested in aircraft power plant development by making available an authoritative, excellently illustrated work covering the entire Diesel aircraft engine field. His wide experience both in this country and abroad makes him a competent proponent for this type of aircraft motive power.

Charles L. Lawrance, Past President of the Institute of the Aeronautical Sciences, and Lt. Col. J. T. C. Moore-Brabazon, President of the Royal Aeronautical Society, have written dual forewords in which they express their high esteem of the book.

Heretofore, there has been no book which covered the entire subject. Only by reading many articles could an impartial or unbiased point of view be obtained. By giving the reader a complete history of this type of engine as adapted to airplanes and airships, a background is provided for the complete description of all existing Diesel aircraft developments. The excellent engineering data given for each engine as well as the airplane or airship in which it is used makes the book the standard reference work in its field. By using both the English and the metric systems, the book becomes useful for all engineers. The chapters on Construction Details, Superchargers, Fuel Injection Systems, and Diesel Fuels are especially complete.

The author can be excused for his optimistic chapter on Advantages for Airline Operation, as he presents it as an engineer to other engineers and not in generalities.

The only element missing in the book is a comprehensive bibliography. Until the Institute compiled such a list of references on Diesel engines, it was difficult to procure. It is now available at the Institute offices and should provide an excellent supplement to Mr. Wilkinson's book.

As the book was published by Mr. Wilkinson privately as a service to aeronautical workers, it is not inappropriate to suggest that his only reward will come from a sale sufficient to cover his original outlay.

Encyclopaedia of Aviation, edited by SQUADRON LEADER C. G. BURGE; The Pitman Publishing Corporation, New York, 1936; 642 pages, $5.00.

Another indispensable reference book on aeronautics has been compiled by Squadron Leader Burge. The new encyclopaedia has the unique quality of interest as well as being a storehouse of information. The usual dullness of such reference works has been avoided by including well selected and profuse illustrations. The first sixty pages are devoted entirely to a pictorial representation of the conquest of flight from the time of Leonardo da Vinci. The reference part of the volume combines the usual short encyclopedic sketches with a series of comprehensive articles divided into fourteen groups: Aircraft, Engines, Mechanics of Flight, Practical Flying, Research and Technical, Equipment, Military Aircraft, Commercial Aviation, International Aviation, Ground Organization, Regulation of Air Navigation, Personal, Historical and Air Medicine.

Each of these subdivisions has several leading articles covering the subject.

The encyclopaedia is therefore a text book as well. It is particularly helpful in its chronologies, lists of records, prizes, races and flights. The biographical section while short contains short sketches of many of the leading figures in aviation. The book is a welcome addition to aeronautical reference books.

Bird Flight, by GORDON AYMAR; Dodd, Mead & Company, Inc., New York, 1936; 234 pages, $4.00.

There are many students of aerodynamics who like to investigate the origins of flight. They are usually so office-bound that they cannot find the time to do the field work required to observe the actual flight of birds. For them Mr. Aymar's book will be a delightful source of data.

The hundreds of illustrations of birds of all kinds in flight show nearly every evolution a bird can perform in taking off, soaring and alighting.

The chapter on aerodynamics discreetly confines its attention to the characteristics of bird flight and by extraordinary pictures illustrate birds that use the principles of the helicopter or slotted wing. Altogether, the book is a diverting interlude for the aeronautical specialist.

Some Observations on European Aviation

Presented at a Meeting of the I. Ae. S. at the N. Y. Museum of Science and Industry, April 3, 1936

STEPHEN J. ZAND, *Sperry Gyroscope Company*

The Journal of the Aeronautical Sciences, from time to time, will publish papers from its members who have been abroad giving reports of the latest aeronautical developments that they have observed. Dr. Zand, a Fellow of the Institute, has had exceptional opportunities to become acquainted with recent progress which he outlines in this paper.

THE EDITOR

INTRODUCTION

DURING the author's recent six months stay in Europe he had the opportunity of seeing in different countries, namely France, Germany, Italy and Poland, the latest types of European airplanes, engines and accessories.

On this, as well as on two previous trips in the last two years, all traveling was done by air, including Asia Minor, and so the author is in a position to report both as an engineer observing trends in European aircraft construction and as an American airplane passenger reacting to European air transport.

Back in 1920 Europe had already a fairly well organized commercial air service. In America air transportation started about 1927, so one might expect that Europe, having had five or six years more experience, would still be leading America by a wide margin. As a matter of fact, the balance of supremacy wavered at all times in the years since 1927. To say categorically that this or that continent leads in civil aircraft is much too risky, as shall be seen later. Conditions here and conditions in Europe are so different that a direct comparison would be decidedly unfair.

American commercial airplanes in the last few years have become extremely fast, safe and comfortable. Europeans saw the challenge of American research and design and immediately set to work to improve their own products. In Europe, in general, and in France, in particular, the policy of the government is to encourage aeronautics not only morally but also financially. Great sums of money are spent in the form of subsidies to foster aircraft. Prizes and premiums up to 10,000,000 francs (about $600,000) are offered for the solution of specific problems.

FRENCH DEVELOPMENTS

The necessity of speeding up schedules and increasing comfort on French airlines was recognized, and so, in connection with this thought, a stop-gap airplane was quickly developed, the Potez 62. It will be recalled that the Curtiss Condor XT-32 was developed

FIG. 1.

and stepped into the picture until such time as it could be superseded by the still more modern Boeing 247-D's, the Douglas DC-2's and others.

The Potez 62 is a development from a bomber and is of mixed construction. It is a sesquiplane with an extremely small lower wing which connects the two engine nacelles into which the landing gear is retracted. Structurally, it is of very interesting design. The wing is of metal, covered with fabric, while the fuselage is made of plywood. The development of the Potez permitted Air France to have an airplane on short notice which cruises at about 160 m.p.h. and lands sufficiently slow. The engines used are air-cooled 14-cylinder Gnome-Rhone KRSD's developing about 900 hp. at take-off. The interior arrangement of this airplane is good. It has two cabins, the forward one for six people, and the rear one for ten. The airplane has been semi-soundproofed. Inasmuch as the structure was built a long time ago, very little could be done towards a really efficient acoustical treatment.

An entirely different airplane (see Fig. 1) is the Wibault 670 which has just been finished. This airplane can be classified as the most modern of all the designs seen in Europe. It is a low wing bimotored plane of full monocoque construction, and at first glance resembles any of our modern metal aircraft. This is so of necessity—in time all airplanes will look alike, for there is an optimum form for this general type. Unlike the automobile into which the artist and the designer can put a lot of individuality, the outside

of the airplane is extremely closely governed by certain basic laws and facts.

Optimum Form in New Designs

Let us assume that an 18 passenger, 200 m.p.h. airplane is to be built. The moment that the placing of the passengers is decided upon—let us say two rows of nine passengers each,—the width of the fuselage is established within a few inches. Since the width of the seat consistent with comfort is known to be twenty to twenty-two inches, and since the minimum aisle space is twelve to fourteen inches, the total width of the fuselage is determined. It is also known that the distance from seat to seat, for full comfort, has to be roughly three and one-half feet. The length of the cabin is therefore established. In a modern airplane it must be possible to walk straight without bending or stooping down. A tall man wearing a hat will require, roughly, about six feet eight inches. The height of the fuselage from the floor is therefore also established. These dimensions will give a sufficient number of points to trace the cross-section of a perfect fuselage. This cross-section should be elliptical.

Having decided to carry eighteen passengers with their baggage we know exactly what their weight is going to be. Adding to this the weight of the structure and the weight of the gasoline to be carried the necessary power that will enable this airplane to take off can readily be found.

Since there are regulations as to minimum landing speeds and since landing speed is a direct function of the area of the wing, another figure, that of the span of the wing, is obtained. Since the power necessary for take-off is already found, the height from the ground will be governed by the fact that it is necessary to have a certain minimum clearance between the propeller tip and the ground. The height of the center line of the airplane above the ground is therefore determined. To sum all these factors up, if it is decided to build a low wing monoplane, the designer has very little freedom in the matter of the shape of his airplane. Therefore, in looking at the Wibault 670 we are inclined to think that it looks very much like the Douglas DC-2.

Externally, the Wibault bears a very close resemblance to the DC-2. In the details of the structure, however, there are great differences. The fuselage, while full monocoque, is built in three separate units, each terminating in a stress taking bulkhead and bolted together with the preceding section. The reason for this construction is to make possible the shipping of complete sub-units of the fuselage by train should such necessity arise, the size of the sub-units being governed by the dimensions of French freight cars. Back of the cockpit in the fuselage is an absolutely up-to-date

Fig. 2.

kitchenette-bar service. Next to the bar is the radio compartment with a radio direction finder loop which can be retracted in flight. Then comes the cabin with nine people on each side. The design of this cabin provides the last word in passenger comfort. All the experience gained in making passengers comfortable in the Douglas, Martin, Sikorsky and other airplanes has been incorporated in this cabin, and it has been acknowledged that the heating, ventilating, and acoustical treatment of this plane established a new standard of passenger comfort. This does not mean that the next American transport airplane will not surpass this one as the art is still very young and there is still much to be learned in the matter of comfort for passengers.

The wing of the airplane is of metal stressed skin construction, is a three spar type, and is of fairly conventional design. Instead of the split flap the ship uses a Fowler flap which enables the airplane to land at about 55 m.p.h. The power plant consists of two Gnome-Rhone 14-cylinder 900 hp. engines with Ratier controllable pitch propellers. The ship is so built that a gyro-pilot can be installed in a few hours, and in short, with its retractable landing gear presents the last word in French airplane technique. The performance of this plane at 7,000 feet is about 200 m.p.h. at 75 per cent full power. A thing worth mentioning is the inherent stability which this airplane and all other European airplanes display. Regulations as to stability are much more rigorous in Europe than they are in America.

In the new program, Air France has included a trimotored airplane, the pictures of which (see Figs. 2 and 3) are self explanatory. Due to the fact that the nose is extremely far ahead of the cabin it was possible to make this airplane fairly quiet and comfortable. The airplane is a thirty passenger Dewoitine to be used for high speed, short range transportation. While the fuselage is of conventional monocoque design the wing is rather unusual for it is the only large airplane using the monospar construction. Mr. Dewoitine was a

FIG. 3.

pioneer in this development and is determined to retain this type of construction.

A newcomer in French civil aviation is M. Bloch, who gained fame as a manufacturer of military aircraft. He is now building a bimotored sixteen passenger airplane and a trimotored thirty passenger airplane, all-metal craft, absolutely modern. Unfortunately, these airplanes were not sufficiently completed to allow of seeing the job through while still in France.

France has to have flying boats in order to have direct connections with her colonies in Africa. A great deal is being done to modernize her flying boat equipment. The *Lieutenant de Vaisseau Paris* is disregarded here, as it unfortunately took a tremendous amount of time to build and should have been ready in 1933. It would then have made the headlines. Today the technique of flying boat construction has advanced so tremendously in America that we can hardly consider it a modern airplane from our point of view. It must be admitted, however, that it was a courageous attempt to get thirty-seven tons off the water and cruise at 120 m.p.h.

Other manufacturers now have on order a superspeed flying boat equipped with 4 Hispano-Suiza engines, manufactured by the Chantier Navals Loire in St. Nazaire. The engines are arranged two in tandem, and it is interesting to note that one radiator suffices for two engines. These planes are supposed to be used on the South Atlantic. Their gas tanks are extremely large but the range of the planes could not be obtained. In any event, commercial aeronautics in France is rapidly becoming one of the best organized systems in Europe, and even now it can be said that Air France is a leader among the many excellent European air transport companies.

When it comes to engines, everyone knows the high quality of the Hispano-Suiza. Hispano-Suiza has been very actively cooperating under certain cross-license agreements with one of our larger engine manufacturers and today they have excellent air cooled engines and also some liquid cooled engines. At this point the author may say that he believes that American companies have committed a certain error in abandoning the intensive development of liquid cooled engines. France, and other countries in Europe, today have liquid cooled engines anywhere from 1300 to 1500 hp. and under certain circumstances the author believes these engines can show to advantage as regards fuel consumption and reliability as compared with air cooled engines. On the air cooled side France possesses the 14-cylinder Gnome-Rhone which has been ordered by their Army in very great quantities and which functions as well as can be expected for a 14-cylinder engine, that is, there are still difficulties in getting proper cooling and satisfactory cowling. Similar difficulties have been encountered in this country with this type of engine but it may safely be said that these difficulties are temporary and probably will be solved in the very near future.

DEVELOPMENTS IN GREAT BRITAIN

Turning now to Great Britain, it must be stated that it has, for the next two years, probably the most ambitious airplane program of any country. The English are naturally interested in the development of large flying boats so as to be able to link the remotest parts of the British Empire with the mother country by this means. Short Brothers are developing what is known as the Imperial flying boat. Every firm which was visited in England had some new transport airplane on their drawing boards, and it is expected that 1937 will see a complete retirement of those strange looking four engine airplanes which fly every day from London to Paris in two and one-half hours. The British are extremely conservative and so patriotic that as long as there is one seat on a British airplane, they are going to stick to their own.

In matters of structures England is to be credited with the development, by Mr. Wallis of the Vickers Company, of what is known as the geodetic[1] structure, an unusual development of which the practical value has still to be investigated.

Imagine for a moment a streamlined form made of wood or metal and imagine that two points on the surface, a certain distance apart, are taken. The streamlined form, being a curved plane, will enable an unlimited number of lines to be drawn joining these two points. The shortest line between those two points will form a geodetic line. If this streamlined form is flattened into a plane, then the junction of those two points in such a projection would be a straight line. Geodetic construction looks like a giant basket and its weight-strength ratio is about one third that of the monocoque construction. It appears, therefore, that a

[1] *See:* C. M. Poulsen, *Geodetic Construction*, Flight, January 16, 1936, pages 66–68, and *Great Circle Engineering*, The Aeroplane, January 15, 1936, pages 73–76.

military or civil airplane built on this principle would show extreme lightness, or for the same weight, a load factor much superior to that of a standard construction. In practice, the author does not know how geodetic airplanes are built. It might be an extremely difficult construction. It can be visualized that every element of the structure is turned on a different angle. Test samples of the structure shown the author indicated that, assuming the practical method of building the structure has been solved, this type of design offers great possibilities.

England also has a great number of small two and three seaters, some of which offer good accommodations for very little power and the trend is toward the small two engine airplane. Quite a number of designs are on the market and the author understands that they are sold in appreciable quantities. As was said before, the British are extremely conservative, so the author was struck with the enthusiasm for a new craze which originated in France, and could, if space permitted, discuss the pros and cons of the backyard airplane, the Flying Flea, or the *Pou-du-Ciel* (see Fig. 4), which literally translated means Sky Louse.

FIG. 4.

THE POU-DU-CIEL

The author will have to go back to his French experiences in order to give briefly a description of this amusing development. About two years ago, a certain Mr. Mignet started building, in his backyard, a new type of airplane. His idea was that airplanes are too complicated to be flown by everybody. Furthermore, being a true Frenchman, he had a spirit of contradiction and voiced the opinion that the sky should be democratic and belong to everybody. Possessing only a rudimentary knowledge of aeronautics, he finally built a prototype of the present "flea." It is a two wing affair with the front wing movable and acting as elevators. There are no ailerons, only a rudder, and he claims that the ship will bank automatically as soon as rudder is applied. If this airplane were built by a factory and sold through some channels it would not have created any particular enthusiasm nor would it have occupied the controversial position which it does now.

Mr. Mignet wrote a book "Le Sport de L'air," or "Air Sport," one of the most delightful pieces of journalism that the author has ever read. The book is written for the layman, but the aeronautical engineer cannot but marvel at the simple way in which he explains certain aeronautical phenomena. The author of this paper found many misstatements and misinterpreted facts in the book, but could not help liking it. This work has been published and sold, it has been said, over 20,000 copies in a short time. The book contains many veritable insults to the aeronautical profession, for example, the author says that all the wind tunnel testing, all the scientific work done by government agencies, all the regulation by the government, are devised solely for the purpose of preventing the man in the street from learning to fly. He and only he has the key to popular flying in his "Flying Flea." The immediate effect of this book, which was given much publicity, was that the French public became divided into two groups, one the "Pou-de-Cielists," and the other, the "Anti-Pou-du-Cielists." The backyards of many mechanics, of many people who previously were building radios, became tiny airplane factories as Mr. Mignet gave all the necessary information on how to build a "Pou-du-Ciel."

There are on the French market small engines of fifteen to thirty hp. which can be bought for about three hundred dollars. Parts for the structure can be bought in the French equivalent of our five-and-ten, as parts were once bought here for homemade radios. A "Pou-du-Ciel" can be constructed, including engine and propeller, for about seven hundred dollars. Clubs have been formed and in many a little field in France on Saturdays and Sundays men can be seen working on their jointly-owned airplanes and trying to get into the air.

Learning to fly a "Pou-du-Ciel" is a one-man affair, for the plane will not hold two men, and the courage of these neophytes must be admired. The "Poux" are barred from official airports until such a time as the technical service will test and give them a certificate of approval. They fly, accidents have happened, and in the authors opinion just as soon as the flying season starts there will be many more accidents. This year there will probably be three or four hundred "Poux" built, and while the author is still convinced that there are other, more reliable ways of investigating the possibility of a cheap, popular airplane, Mr. Mignet and his followers cannot but be admired for their enthusiasm and perseverance in bringing airplanes within the reach of the average man. The fact that the English have taken up this sort of flying sport seems to indi-

cate that perhaps there are some hidden virtues in this design and only the future can show who is right. Flights across the Channel have been made and some of the "Poux" fly remarkably well.

German Developments

The author did not see any German military airplanes. He does not believe that Germany has a great fleet of military airplanes yet but in matters of civil aircraft she has the old standby Junkers, the latest model of which, the JU-52, is an orthodox machine, heavy, not too comfortable, fairly fast, and is understood to be amazingly inexpensive to operate. Their latest two-engined Junkers follows very closely the trends of American and French aircraft, and when seen from the outside looks like an extremely successful machine. The Heinkel Works have just finished a ten passenger high speed water-cooled two-engine job of very clean lines said to fly at 200 m.p.h. The American influence can be seen on this airplane, except for the interior, which compared to our standards is much too crowded.

In engines, Germany is certainly far ahead in the development of the Diesel with some very successful designs. Their development in air-cooled engines has been rather slow and Germany was largely dependent upon licenses from our air-cooled engine manufacturers.

Polish Developments

The production of civil aircraft, except for private use, has been practically abandoned in Poland. The author believes this to be a very wise move since the number of civil aircraft of the transport type to be used in Poland is very small. Ten airplanes will take care of many a mile of traffic. So Poland has bought some Douglasses and Electras with British Pegasus Bristol engines, and Gyro-pilots, which they use on international lines. On domestic lines, the Fokkers which they have built under license in their own factories are sufficiently fast to take care of the traffic.

The author visited, in Poland, the government factory, which is now manufacturing both engines and military airplanes, and must say that the degree of progress made by this country, which, as is known, started from scratch in 1918, is amazing. The new Warsaw airport is the last word in design. The machine shops and assembly shops are organized with typical American precision, and on entering the PZL Works in Warsaw one cannot but feel that the Poles have watched us very closely, and the missions which were frequently sent to the United States have derived great benefit from what they could learn here. Their pursuit ships are considered among the best in Europe and their three seater RWD won the *Challenge Internationale de Tourisme Aerien* twice in succession, securing permanent possession of this much coveted trophy.

Italian Developments

The Italians have always been known as extremely good and courageous designers. Up to 1932 they leaned toward wood and mixed steel and wood constructions. Upon the arrival, after a three months' stay in America of Mr. Gabrielli, chief aeronautical engineer of Fiat, the policy was changed and the all metal technique gained impetus. The Fiat G18 resembles our American designs on the outside. Its structure, however, is entirely different, and so are the engine mounts. The performance is exactly like that of any one of our machines and there are ten of them operating on the Italian airlines. The airplane is 100 per cent Italian as the engines are also of Fiat's own make. A different type of airplane has been developed which has the amazing speed of 220 m.p.h. It is powered by two 14-cylinder Fiat engines and carries ten passengers. The details of this airplane were not seen. On the military side the Italians have some extremely good airplanes.

Regarding European airplanes and engines, it may be safely said that there is not a single design in Europe which does not come up to the American standard. This does not mean, however, that we should abandon all efforts to export American aircraft to Europe. When it comes to the price of European aircraft it appears to the author that the advantage is with us, as American airplanes cost from 25 to 35 per cent less to produce than similar European types.

European Transportation Problems

It is very often inferred that European air transport is way below the standard set by airlines in the United States. Conditions in Europe are very different than they are here. The author has flown more than 15,000 miles, not as a privileged passenger, not as a man traveling on a courtesy pass, but as a paying customer of different airlines. European airlines are confronted with different problems than those operating in the United States because conditions geographically, politically, and ethnographically are different than ours Draw a circle from Paris as a center with a radius equivalent to the distance from New York to Los Angeles. In order to make that distance we have to cross 14 borders with 14 different languages, 14 different money exchanges, 14 different governments, 14 different mental attitudes, 14 different telegraph and telephone systems, and many other 14 things too numerous to mention. For example, if a man is making a reservation from Paris to Constantinople and through some reason or other has to travel through Rome, he will have to take a French air line to Marseilles, an Italian air line to Rome, an Italian-Greek

line to Athens, and an Italian-Greek-Turkish line to Constantinople.

The fact that European air travel systems exist and that they do work smoothly is an indication that Europe is getting nearer toward friendly international relationships. The author has gained the impression that other nations are rapidly gaining on the United States in aeronautical progress because their governments have adopted vast comprehensive programs for aeronautical development. Unfortunately, the United States does not have as yet a National Aviation Program. The fact that the United States is still leading in the aeronautical industry is primarily due to the enthusiasm of its private enterprises and the author believes the time is near when this enthusiasm should be backed up by a coordinated governmental policy.

Aircraft engineering has now become a problem of group specialization. So many different branches of science are now required by designers of airplanes that no one engineer can hope to become proficient in all. All countries are learning that progress must come from laboratory tests and experimentation by highly trained specialists. For many years the United States has been far in the lead in experimental work, but with the huge wind tunnels, towing basins and testing equipment that are being installed in Europe, the United States must look to her laurels.

The United States has the scientific workers, the engineers and the designers, and these men can continue to lead the world if given a plan and a program. Given these, this country's defenses will remain secure and its aircraft supreme.

Book Reviews

Jane's All the World's Aircraft, edited by C. G. Grey and Leonard Bridgman; Sampson Low, Marston & Co., Ltd., London, 1935; £2/2/0.

As the aircraft industry of every country of the world increases and types of airplanes and engines become more numerous, "Jane's All the World's Aircraft" becomes by its number of pages an index of such growth. In no other volume that we know can there be found such a wealth of information regarding air development in all parts of the world. For twenty-five years, Charles G. Grey, the editor of "The Aeroplane," assisted for many of these years by Leonard Bridgman, has rendered a useful service to all who wish to secure information regarding the aeronautical organization of various countries as well as to those who wish to have available for reference a description of practically every airplane, seaplane and engine (not on a secret list) which is manufactured in any country.

Pictorially the book is unsurpassed, containing, as it does, 602 pictures of airplanes and 159 pictures of aeronautical engines.

In his preface, Mr. Grey explains why some aircraft do not appear, for reasons which indicate the urgency that exists in England for enlarging the Royal Air Force.

"The Supply Department of the Air Ministry has displayed extraordinary courage in that it has ordered quite large quantities of aeroplanes straight off the drawing-boards, subject only to the constructors' guarantees that they will perform according to specification. That means that we shall have by the end of next year actually flying, if not in the squadrons of the Air Force, a number of aeroplanes which if they had been ordered according to the normal procedure of the Air Ministry of the past would not even be in the air till about the end of 1938 and could not be regular equipment of the Air Force Squadrons until 1942."

Surely the millenium has arrived for aircraft firms in England!

A study of the trends indicated by the new volume shows that speeds of 200 m.p.h. are quite ordinary and Mr. Grey gives hints of machines still on secret lists of 300 m.p.h. and more in several countries. The more general use of the retractable undercarriages and the extreme streamlining of modern aircraft, the cowling of motors and the use of supercharged engines are apparent. Air cooled and liquid cooled power plants appeal to different countries with varying degrees of approval.

Even as experienced a classifier as Mr. Grey has difficulties in placing the new small airplanes developed in France. He compromises by listing them as "playthings."

The only failure to live up to the completeness which is in evidence in other parts of the volume is the part dealing with International Records. Here only a few of the principal records are given. It would be better to have left them out entirely, as Mr. Bridgman wished, than to give the small incomplete list which might give an impression that these were all the records homologated by the F. A. I.

The section dealing with the United States is particularly complete, but its accuracy is marred by reference to the Institute as an "Institution," which has a meaning all its own in aeronautical circles in this country—as being a place where pilots and aircraft manufacturers may eventually be incarcerated.

Every person who has any connection with aeronautics should feel indebted to Mr. Grey and his associates for the immense effort they expend for the benefit of the aviation world. No financial return can pay for such work. The renewed appreciation from those who have found "All the World's Aircraft" indispensable is the only worthwhile reward that comes for the drudgery that is necessary in compiling such a work.

Der Soldatenfreund. Wehrverlag Joseph Bercker, Berlin, Germany, 1936; 200 pages including 22 color plates, 1.35 RM.

This small handbook discloses the new organization of German Air Forces as well as that of the new military and naval establishments. But it goes much further. It also makes available to the new German recruit general information regarding the heads of the government, memorial days, warfare in all its various forms, and military law. It contains a diary and concludes with twenty-two color plates showing the new German uniforms and insignia for rank and service for the many uniformed groups of the Reich. It has an interesting section devoted to aviation, its history, chronology, records and development. Of particular interest is the description of the official league for defense during attacks by air which now numbers eight million members.

Propeller Advances

Presented at the Propeller Advances Session, Fourth Annual Meeting, I. Ae. S.

FRANK W. CALDWELL, Chairman
Hamilton Standard Propellers
Division of United Aircraft Mfg. Corporation

In a general discussion of the subject of propellers, we like to divide the subject into headings of Aerodynamics, Relation to the Power Plant and Propeller Design. I shall try to outline briefly some of the subdivisions which I hope the other speakers will discuss.

Under the heading of Aerodynamics, the Aerodynamic Design of the propeller may be included and such factors as Planform, Camber Ratio, Aspect Ratio, Number of Blades, Effective Pitch Ratio and Critical Tip Speeds.

With relatively slow airplanes and engines of moderate horse power, the propeller designer was able to indulge his fancy in the selection of the propeller design without a very serious effect on airplane performance. Even under these conditions, we were tending to use propellers of excessive diameter and blade area because the low blade angles resulting gave improved takeoff in spite of the excessive drop in revolutions of the engine.

As engine power and revolutions went up, we began to get into trouble with losses due to excessive tip speeds and we had recourse to thin metal blades to increase the permissible tip speed and save the direct drive engine.

We finally reached the end of this expedient as tip speeds became excessive, even for the thin blades, and we had to go to reduction gearing. Exactly at the same time, we began to build heavily loaded and highly streamlined airplanes with a very great increase in maximum speed. All of these factors led to propellers of such high pitch ratio that they were stalled at takeoff and these propellers had to be used on planes which were much more difficult to get off.

For this set of aerodynamic conditions, the controllable pitch propellers proved indispensable and we now accept them as a matter of course.

Propeller noise must be associated with aerodynamics and we should have some discussion of this subject.

In the matter of the interrelation of the propeller and power plant, we used to need a rather elaborate set of curves showing limitations of engine power and speed of rotation as affected by altitude and by supercharging. The Constant Speed Propeller has made these curves largely obsolete and we are now able to get along with much simpler ones.

While we have removed the limitations from the engine, we have to analyze the propeller design for more conditions than ever before. Fortunately, the propeller is a rather flexible device aerodynamically and we are not in much trouble yet. It looks as if we might get along all right up to altitudes of about 30,000 feet, but if we really go up into the stratosphere, we shall probably have to do something radical with the aerodynamic design of the propeller.

In addition to the aerodynamic relation of the propeller to the engine, we are beginning to worry more about the interrelation from the standpoint of vibration, particularly as regards the excitation of resonance.

When the matter of propeller design is mentioned, we have to think seriously about weight. The weight of the propeller has now become a ponderable proportion of the weight of the aircraft and considerable effort is justified in order to reduce it.

As engineers, however, we cannot talk about weight except in terms of materials and stresses. The materials which we have principally worked with have been: (1) Aluminum Alloys, (2) Micarta and other Plastics, (3) Magnesium Alloys, (4) Steel, and (5) Wood.

Our success in the use of these materials will depend in a very large degree on a better understanding of the most severe stresses so that we can design away from them. The steady stresses are not particularly difficult and we can account for them in a fairly satisfactory manner. The alternating vibratory stresses which lead to fatigue failures are in a different category, as they are very difficult to analyze. We have assumed that vibratory stresses result from excitation at resonance and from forced vibrations. Efforts to reduce their effects have been mainly directed toward insulation by means of softer drives, etc. and damping.

While it seems improbable that we can analyze the vibration stresses, there seems to be some hope that we can measure them. Quite a lot of work is being done currently on the measurement of vibration stresses. Various kinds of extensometers are being tried, including the following types: (1) Scratch extensometers, (2) Optical extensometers, (3) Magnetic extensometers, (4) Carbon Pile extensometers, and (5) Piezo-Electric extensometers.

The oscillograph and wave analyzers are being used in connection with electric types of pick up units.

In addition, distortion is being measured by spark photography and by reflecting mirrors. There is also considerable effort being expended in relating the sound frequencies and intensities to the vibration stresses.

A Survey of Engine Development

Presented at the Survey of Engine Development Session, Fourth Annual Meeting, I. Ae. S.

CHARLES L. LAWRANCE
Lawrance Engineering and Research Corporation

Mr. Lawrance stated that he was surprised that the aircraft engine industry did not regard the Diesel engine more seriously, as he considered that it had certain features which, for commercial aircraft at any rate, made it much more desirable than the spark-ignition type of engine. The principal advantages were low cost of fuel as compared to the more and more expensive high octane fuels used in aircraft, and the removal of fire hazard. Although the fuel consumption of spark-ignition engines has been much reduced of late, there is always the danger of overheating the engine, and pilots are afraid to use the mixture control, whereas in compression-ignition engines the fuel consumption is inherent and beyond the control of the operator.

He stated that the two-cycle type was the only type which he considered worthwhile, and that while two-cycle engines of the spark-ignition type had never been put successfully in production, the two-cycle type of Diesel was in every way a practical and advantageous engine, and more than counteracted the additional weight of individual parts by the more frequent power impulses.

Institute Notes

American Association for the Advancement of Science

The Institute of the Aeronautical Sciences last year was accepted as an Affiliated Society of the American Association for the Advancement of Science. This connection brings certain benefits to Institute Members, which are indicated in the following statement.

The American Association for the Advancement of Science now constitutes a co-operation of nearly eighteen thousand individuals. It is also a general association of the numerous American societies for the advancement of the special sciences. There are now one hundred and fifty-four organizations, including twenty-nine affiliated academies of science, that take part in the activities of the Association.

The general work of the Association is supported by the contributions of the individual members, which may be sustaining-membership contributions, life-membership contributions, or annual-membership dues.

Each new annual member regularly pays the entrance fee of $5.00 and the first annual dues of $5.00 *but the entrance fee may be omitted by members of any affiliated society* or affiliated state academy. Life members pay no entrance fee but contribute $100 in a single year and pay no annual dues. Sustaining members each contribute $1,000 in a single payment. The fees of life and sustaining members are carefully invested by the finance committee and thus become part of the permanent funds of the Association. Only the income may be expended, first for journals for life and sustaining members, and later for the advancement of science.

Annual, life and sustaining members each receive the official weekly journal of the Association, *Science*, or they may receive *The Scientific Monthly* instead of *Science* if they so request. By special arrangements with the publishers, members of the Association may subscribe for *The Scientific Monthly* at the special price of three dollars per year. Thus, an annual member in good standing may pay eight dollars a year and receive both *Science* and *The Scientific Monthly*.

Application cards and lists of associated and affiliated societies and affiliated state academies may be obtained by addressing the office of the permanent secretary, Smithsonian Institution Building, Washington, D. C.

Student Branches

University of Detroit. The second meeting of this Student Branch was held February 26 in the University of Detroit's Engineering Building. Robert W. Ayer, Engineer in Charge of the Transport Division of the Stinson Aircraft Corporation, gave a talk on the "Design and Operation of Feeder Transports." Moving pictures on "Airspeed Indicators" and on "Radio Beacons" were obtained and presented through the courtesy of the U. S. Army Air Corps. Forty Student Members attended the meeting.

Another meeting of this branch was held on March 31. Karl Day of American Airlines spoke on "Blind Flying" and M. C. Haddon, Chief Engineer of the Hammond Aircraft Corporation, gave a talk on the Hammond plane being tested at present, entitled "Problems in Design of Private Owner Airplanes."

Rensselaer Polytechnic Institute. The first formal meeting of this Student Branch of the Institute was held Thursday, March 12th. P. E. Hemke, head of the Aeronautical department of the school, gave a talk on "Streamlining." The meeting was well attended.

University of Michigan. The first meeting of this Student Branch of the Institute was held Wednesday, March 25th, in the East Engineering Building of the University. Burdell L. Springer, Honorary Chairman of this branch, presided. Officers were elected at this meeting, and in the general discussion held later, plans for the activities of the branch were suggested and made.

The second meeting of this Student Branch was held Thursday, April 2, 1936.

The Chairman stated that the meeting was to be conducted as a seminar, the subject being, "A Review of Recent Advances in the Use of High Lift Devices on Airplane Wings."

Professor M. J. Thompson, of the Department of Aeronautical Engineering, was guest speaker. Professor Thompson gave a short talk on the use of wind tunnels to determine yawing, pitching, and rolling moments on models with flaps, ailerons, or other special high lift devices. He discussed some of the problems and difficulties involved in accurately measuring the moments of these devices, especially the hinge moments of Fowler or split flaps.

Paul Bremer, a graduate student, spoke about his research problem of last semester. It involved the use of double flaps, the first of these located at 55 per cent of the chord, and the second at 80 per cent of the chord. The research is not complete but the results obtained show an optimum of a 90 per cent increase in the maximum lift coefficient of the wing.

George Graves, Program Chairman, gave a summary of N. A. C. A. Technical Report No. 537. This report concerns an investigation of split and Zap flaps, as conducted by the National Advisory Committee for Aeronautics. He reviewed the method of obtaining the optimum lift coefficient. The questions of pitching moments, hinge moments, and lateral control were discussed by various members. Burdell L. Springer, Honorary Chairman, added a few remarks and general observations relative to the aerodynamic effects of changes in the position and location of hinged flaps.

Rudolph Thoren, graduate, spoke about the results of his research, under Professor E. A. Stalker, on boundary layer control. The set-up involved the use of compressed air to remove the boundary layer by adding to its energy. Several shapes of wings were used, with an optimum result of $C_L = 4.98$. The drag coefficient for lower values was negative due to jet action of the compressed air being expanded through slits in the surface of the wing. However, the power necessary to obtain this high lift coefficient is the most serious difficulty involved in the use of this type of boundary layer control.

Chairman McCance gave a summary of N. A. C. A. Technical Report No. 534, on Fowler flaps. With a consideration of the weight of the flap, the optimum value of the lift coefficient was 2.75, obtained with a 30 per cent chord flap rotated downward thirty degrees.

The Institute Library

Through the gifts from members and books sent for review as well as books, pamphlets and reports sent for the Institute files a library of about a thousand volumes has been accumulated at the Skyport. With the Index of aeronautical books, magazines, reports and papers nearing completion it is becoming increasingly necessary to have available for members and others who request information an adequate selection of books which may be referred to without going to other libraries. The Institute does not wish to house a large collection of books but should have a representative library.

Members are urged to send to the Institute Secretary a list of any books and other printed matter which they are willing to present to the Institute library. Scientific and engineering books are particularly desired. Each book will be marked with the name of the donor and the gift acknowledged in the Journal.

Lectures

A series of lectures are being organized to be given before sections of the Institute in cities where there are enough members to provide an audience of sufficient size to warrant a speaker coming from a distance. Already, meetings have been held in Washington, Los Angeles and New York. Members in Philadelphia and Akron are making plans to hold meetings during the year. Will members who wish to organize regular sections and hold meetings communicate with the Secretary who will assist them to secure speakers.

Meeting in Rochester

The Institute will hold its first meeting as an affiliate of the American Association for the Advancement of Science in Rochester on June 19th. The subject of the session will be Aerial Photogrammetry and there will be a program of the greatest interest to all those members who are interested in this activity. Mr. Leon T. Eliel of the Fairchild Aerial Surveys will be Chairman and among the speakers presenting papers and taking part in the discussion will be: Col. C. H. Birdseye, Geological Survey, Department of the Interior; Lt. O. S. Reading, Coast and Geodetic Survey; Dr. Walter Clark, Eastman Kodak Co.; Capt. Louis J. Rumagge, U. S. Army Air Corps; Marshall S. Wright, Soil Conservation Service; Charles W. Collier, Soil Conservation Service.

Lecture by G. W. Lewis

On Tuesday evening March 3rd, Dr. G. W. Lewis, Director of Research of the National Advisory Committee for Aeronautics, gave a lecture before members of the Institute and others at the New York Museum of Science and Industry in New York City. His subject was "The Application of Science to Aeronautics" and he presented a resumé of the paper of Eastman N. Jacobs on "Methods Employed in America for Experimental Investigation of Aerodynamic Phenomena at High Speeds," with motion pictures of tests made in the "superspeed" wind tunnel at Langley Field. These pictures showed the "shock wave" that occurs when the air flow over an airfoil reaches a speed of about 575 m.p.h.

Necrology

The death is announced in the London papers of Sir Joseph Petavel, a MEMBER of the Institute who was Director since 1919 of the National Physical Laboratory at Teddington and a member of the Aeronautical Research Committee. He was a distinguished physicist and mechanical engineer whose early work in meteorology and in the fields of light, heat, high pressure, and explosion led to his appointment as director of the N. P. L. to succeed Sir Richard Glazebrook. It may be recalled that the N. P. L. consists of a group of laboratories roughly corresponding to our own National Bureau of Standards plus the Langley Memorial Laboratory of the N. A. C. A. In addition, the N. P. L. includes the Froude Tank for research on ship propulsion.

Joseph Petavel was educated at University College, London and for some years was engaged in research at the Davy Faraday Laboratory of the Royal Institution. He was from 1908–19 Professor of Engineering and Director of the Whitworth Laboratories of the University of Manchester. Important early contributions were: "Investigation of the Upper Atmosphere," Nature, 1908; "The Pressure of Explosion: Experiments on Solid and Gaseous Explosives," Phil. Transactions, 1905; "Meteorological Observations at the British Kite Station (1906–9), Journal Royal Met. Soc., 1906.

In 1920 Sir Joseph was created Knight Commander of the order of the British Empire in recognition of his contributions to physics, engineering, and aeronautics. He was a Fellow of the Royal Society and of the Royal Aeronautical Society, a member of the Institution of Mechanical Engineers and the Institute of the Aeronautical Sciences, as well as an associate member of the Institution of Civil Engineers and of the Institute of Electrical Engineers.

Sir Joseph was an engineer whose background of basic science enabled him to work in the broad field of applied science without restriction to any one of the rather narrow fields into which engineering practice has become divided. As Director of the National Physical Laboratory he was most effective in the encouragement and guidance of a brilliant staff working in every field of applied science, with particular emphasis on the aeronautical sciences.

The hospitable Bushy House, the residence of the Director, will be remembered by many of our members who have visited Teddington.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here by permission of the Chief of the Air Corps. The articles listed may not be obtained from the Army Aeronautical Museum Library as these magazines are available to Wright Field personnel only.

Aerodynamics

The Deutsche Versuchsanstalt fuer Luftfahrt in the Year 1933/34. J. Braemer. Survey of research covering measuring apparatus and methods of measuring, flow and flight mechanics, strength of materials, airplane-engines, and equipment. V.D.I., February 8, 1936, page 153.

Electrically-Controlled Balance for Minute Measurements and Remote Recording of Measured Values. M. Kramer. Electrically-controlled balance for the six-component scale of the D. V. L. large wind tunnel. Very detailed description. V.D.I., February 8, 1936, page 141.

Germany. New engine and airplane testing tunnels erected at Adlershof Airport, Berlin. Few details only. Aero Digest, March, 1936, page 66.

Note on Boundary Layer Flow. H. B. Squire. Flow along a flat plate and effect of pressure gradient on the transition of the boundary layer from laminar to turbulent, and on break away are reviewed in the original report. Brief abstract of British Aeronautical Research Committee Reports and Memoranda No. 1664. Aircraft Engineering, March 1936, page 88.

On the Effects of Cutting Away the Trailing Edge on the Aerodynamic Characteristics of a Wing. T. Okamoto. Forms for the cutaway section are studied. Abstract of the Tokio Imperial University, Aeronautical Research Institute, Report No. 131, November 1935. Aircraft Engineering, March 1936, page 86.

Rolling and Yawing Moments on Half Wings with Various Modifications of Wing Tips. D. H. Williams. Half a wing only was mounted in the four-foot wind tunnel with the root of the half wing at the wall of the tunnel, and rolling and yawing moments about the wind axes were measured. Results only given in the brief abstract of the British Aeronautical Research Committee Reports and Memoranda No. 1665. Aircraft Engineering, March 1936, page 88.

Tests on Aerofoil Flaps in the Compressed-Air Tunnel. R. Jones, A. H. Bell and E. Smyth. Chief results of tests conducted at the N. P. L. upon Schrenk flaps attached to a R. A. F. 48 airfoil. Abstract of British Aeronautical Research Committee Reports and Memoranda No. 1636. Aircraft Engineering, March 1936, page 87. Outline of report only. Aero Digest, March 1936, page 39.

Theory of Turbulence, Momentum Transfer and Interchange of Vorticity. C. Ferrari. The problem studied is based on the theories of Taylor and Prandtl in comparison with those of Von Karman, Mattioli and Gebelein. Brief abstract from L'Aerotecnica, November-December 1935. Aero Digest, March 1936, page 39.

Wind-Tunnel Tests. Contents only of the second report on experiments of the aerodynamical laboratory of the Royal Engineering Institute of Turin. Abstracted from L'Aerotecnica, November-December 1935. Aero Digest, March 1936, page 38.

Airplane Design

Aeronautical Meeting Feature of National Pacific Aircraft Show. "Design Problems of Two-Engined Aircraft," H. L. Hibbard; "Radio and Electrical Aids to Air Navigation," A. A. Barrie, and "The Government's Interest in Aviation," J. S. Marriott. Abstracts only. S. A. E. Journal, March 1936, page 21.

Aircraft Sessions. The Weick, Koppen and Wood papers are discussed by E. G. Reed, F. S. Spring, R. H. Upson, G. Higgins, T. P. Wright, C. H. Chatfield and others. Papers themselves appeared in previous issues. S. A. E. Journal, March 1936, page 36.

Commercial Efficiency. S. J. Noel-Brown. Further criticism of the Bentley formula for the commercial efficiency of an airplane, including number of passengers and engines, and metal versus wood construction. Flight, February 27, 1936, page 232.

Elevator Trimming Tabs. G. V. Lachmann and R. S. Stafford. A graphical method for their design derived from actual tunnel results with additional information to that given in the Serby article published in the December issue. Aircraft Engineering, March 1936, page 71.

The "Hemiptere" of Pierre Mauboussin. Unusual single-seater 40-hp. light plane described as a biplane. The upper wing is located at the tail and carries ailerons as well as vertical planes at the tips for increasing maneuverability. Aerodynamic characteristics of the design are said to be particularly interesting and the plane is easy to pilot. Long description. Les Ailes, February 13, 1936, page 4.

Random Notes on a Visit to the United States and Australasia. W. S. Shackleton. Unusual features in the construction of Curtiss and Waco airplanes and the Curtiss propeller from a British point of view. The Curtiss features discussed include: double forgings, use of aluminum foil instead of dope resisting paint, self-tapping screws, Curtiss-Handley-Page slats, automatic-feed riveting machines, fabric fixing strip, and design of the controllable-pitch propeller. The Waco features in the second article cover raft jigs, rotatable fuselage mounting, testing shock-absorber struts, Jacobs L 5 engine, Waco inspection panels, adjustable cabin seats, and vibration testing of tanks. The reference to Wright Field is very brief. Aeroplane, February 26 and March 4, 1936, pages 258 and 289.

Tapered Wings and Safety. G. V Lachman. Answers to criticisms of W. R. Andrews. Object of the previous article was to show how distribution of induced velocity across the span of a fully tapered wing (especially when the latter is fitted with a partial flap) can utilize the beneficial aerodynamic characteristics of the slot to the fullest extent. Reference is made to American results to substantiate his theories. Flight, Aircraft Engineer Supplement, February 27, 1936, page 16.

Thirty Hours of Flight in a Helicopter. A new de Asboth design of helicopter, said to solve the problem of practically vertical take-off, and four previous de Asboth designs are described. It is said that the British government has developed a helicopter based on these new principles and that Blackburn has acquired the exclusive license for it. Les Ailes, February 20, 1936, page 5.

Trimming and Balance Tabs. C. J. Wenzinger. Functions and kinds of tabs are explained by N. A. C. A. definitions. Letter replying to editorial in December issue. Aircraft Engineering, March 1936, page 88.

The Use of Split Flaps and Other Devices for Facilitating Landing. S. B. Gates. Indications helpful to designers obtained from results of recent experimental work. Abstract of British Aeronautical Research Committee Reports and Memoranda No. 1659. Aircraft Engineering, March 1936, page 88.

Automatic Stabilization. F. Haus. Automatic longitudinal and lateral stabilizers for airplanes. The designs of the S. E. C. A. T., Siemens-Boykow, Gianoli, Sperry, Smith, Pollok Brown, Robert, and Askania stabilizers are discussed. Continuation of article. L'Aeronautique, L'Aerotechnique Supplement, January 1936, page 1.

The Claude "Canard" Safe Airplane. The new type of "Canard" airplane designed by Leon Claude is said to descend like a parachute. The main wing is located at the rear of the fuselage. The smaller wing at the front of the fuselage is articulated for 25 per cent of the leading edge. The design of a light two-seater plane is discussed, together with its theoretical performance calculated from the model results. Polars obtained in wind-tunnel tests of the model are illustrated to indicate the advantages of this type of plane. Les Ailes, February 6, 1936, page 4.

Commercial Efficiency. S. J. Noel-Brown. Criticism of E. N. B. Bentley's formula for assessing the commercial efficiency of aircraft, which appeared in the January 9 issue of the magazine. The formula is considered impractical as it fails to include factors of the greatest importance to air-line operators. Errors in the letter of W. D. Brown in the January 23 issue, also discussing the Bentley article, are pointed out. Replies of both Brown and Bentley to these criticisms are given in the second issue. Flight, February 6 and 13, 1936, pages 149 and 178.

The Direct Control of Lift. L. de Monge. Direct control of lift and the controls of the Pou-du-Ciel are discussed. L'Aerophile, January 1936, page 10.

The Dynamic Phenomena in Wings. P. Richard and M. Richard. Influence of elasticity on the nature of the vibrations and their development in airplane wings. The three following cases are considered: a wing mounted on a fixed spindle around which it may oscillate elastically; a wing flexible in bending and torsion; and a wing flexible in bending and torsion and equipped with a normal aileron. Loss of stability by divergence, and buffeting are explained. (To be continued.) L'Aerophile, January 1936, page 7.

Factors Affecting the Cost-of Airplanes. T. P. Wright. Effects of quantity production, design, tooling, and size on the cost of airplanes. The influence of labor, material and overhead in making cost reductions possible with increase of quantity produced is discussed and the cost per pound of structure, or of airplane light weight, is considered. An example is given for determining the anticipated variation in price with quantity. Journal of the Aeronautical Sciences, February 1936, page 122.

The Influence of Aspect Ratio. H. L. Hibbard. Effect of aspect ratio in improving airplane performance, especially in regard to rate of climb, ceiling and landing speed. The Douglas DC-2, Lockheed Electra, Vultee, Northrop Delta and Boeing 247D wing structures are illustrated and discussed. Les Ailes, February 6, 1936, page 5.

Landing on Air. The Faudi-Turner undercarriage compression leg described is an "all-air" telescopic member composed of a cylinder with a stepped piston and a tubular piston rod of slightly smaller diameter than the piston. The cylinder space above the piston is the compression chamber and the annular space between the lower cylinder wall and the piston rod is used in connection with damping the rebound. Flight, February 6, 1936, page 153.

Movable Wings. "Aile vivante" is defined as a wing elastically joined to the fuselage in order to obtain "aerodynamic suspension" and longitudinal "autostability." Means for varying the incidence of the wing and for simultaneously varying both the incidence and camber are discussed. Conditions of longitudinal equilibrium for an airplane with movable wings, and dynamic stability are taken up. A monoplane with wings elastically attached to the fuselage which was designed by Louis de Monge in 1914, the movable wing of the Leyat monoplane, and that of the Pou-du-Ciel are descibed. L'Aerophile, January 1936, page 11.

Remarks on the Vibration of Wings. J. Ackeret and H. L. Studer. Brief abstract from Helvetica Physica, Volume 7, Number 5. L'Aeronautique, L'Aerotechnique Supplement, January 1936, page 16.

Resonance Vibrations. M. Victor. The 3-kg. Rouy brake attached to the wings of a 4-ton airplane is said to dampen the resonance vibrations. This device and a similar one for damping aileron vibrations

are described in connection with a long explanation of resonance vibration and its occurrence in airplanes. Torsional vibration of engines is also discussed. It is concluded that for each wing profile there is a different critical speed of continuous beating of the wing and aileron. Les Ailes, January 30, 1936, page 5.

Tests of the Gerin. The Gerin Varivol variable-surface wing described, consists of a flexible surface mounted on movable ribs, which slide laterally in back of the principal profile. Each of these surfaces, corresponding to each wing, is rolled over electrically turned drums located in the fuselage. The arrangement permits a ratio of 1 to 4 between the extended wing and the reduced surface. Les Ailes, January 30, 1936, page 14.

Vacuum Jacks for Flaps. The Theed double-acting vacuum cylinder described may be adapted to the operation of split flaps for airplanes as well as of other types of flaps, such as the Handley-Page slotted flaps. Aeroplane, February 12, 1936. page 206.

Airplane Performance

The Air Density Effects in Spinning. S. B. Gates and A. V. Stephens. Mass of the model was changed in the experiment to find the air density effects but the center of gravity and radii of gyration remained the same. Results only discussed in this abstract of the British Aeronautical Research Committee Reports and Memoranda Number 1663. Aircraft Engineering, March 1936, page 88.

Flight Tests of Tail Spins. A single-seater pursuit ship, reported to have a tendency to tail spins, was tested with five fins, two elevators and three different centerings. Conclusions said to have been reached in tests in the United States are briefly given with the remark that for delicate experiments American pilots utilize an auxiliary arrangement for restoring equilibrium consisting of a small parachute placed beneath the empannage and released by the pilot at the necessary moment. Les Ailes, February 13, 1936, page 3.

Airplanes

Trends in the Development of Gliding and Glider Construction. E. Steinhoff. Technical improvements in glider design and performance as indicated in the Rhön Glider Competition of 1935. The gliders taking part in the recent contest are said to show decided progress in design over those of the 1934 contest, due to the preferred construction of the semi-high wing monoplane glider. The Rhönsperber, Condor II and Minimoa gliders are described. V.D.I., January 25, 1936, page 99.

FRANCE

A 300 MPH Trio. Notable features of three of France's newest fighters, one with a 1000-hp. radial. Drawings of the Nieuport 160, Loire 250 and Dewoitine D513. Armament of the radial-powered Loire is described and estimated performances of the three planes are given. Flight, February 20, 1936, page 202.

Dewoitine. The new single-seater Dewoitine pursuit ship equipped with an Hispano-Suiza 12-Ycrs motor-canon. Four photographs and theoretical performance only. Les Ailes, February 13, 1936, page 1.

The Pou-103. A light plane constructed by M. Louchet which differs comewhat from the original Pou-du-Ciel. Description of design and flight tests. Les Ailes, February 20, 1936, page 11.

The Flying Flea. A. Klemin. Advantages and limitations of the Pou-de-Ciel light airplane. Scientific American, March 1936, page 146.

Henri Mignet's New "Pou-Bébé." The new Mignet light airplane recently flight tested has a 4-meter wing span, 3-meter length, and weighs 100 kg. Few details only are given. Les Ailes, January 30, 1936, page 11.

The Loire-250 Single-Seater Pursuit Ship. A. Frachet. The all-metal pursuit ship described is armed with four guns and powered by an Hispano-Suiza 79-Ha 1000 hp. engine. The ship is said to have attained a top speed of 485 to 490 km. per hour in flight tests and to climb 5000 meters in five minutes. Long description of the design with very brief reference to armament and theoretical performance. Les Ailes, February 6, 1936, page 3.

The New Dewoitine D.338 and D.620 Transports. The D.338 24-passenger and D.620 30-passenger monoplanes are described. L'Aeronautique, January 1936, page 11.

GERMANY

Aircraft (Luftfahrt). Military, sport, commercial and transport airplanes and engines in Germany. Special publication of the V. D. I. Very brief review. Automobiltechnische Zeitschrift, February 15, 1936, page 78.

Airplane for the People. The Beyer-Weimar flying wing with controllable slots for reducing the landing speed. In the light German airplane described the lifting surfaces are reduced to a single slotted wing without any horizontal tail surfaces. Stability and maneuverability are obtained by the action of a front flap which, in modifying the distribution of the aerodynamic forces over the profile, displaces the resultant with respect to the center of gravity and controls the trim of the airplane. Les Ailes, February 13, 1936, page 4.

The Focke-Wulf "F. W.-58." The light plane for the intensive military instruction of pilots is powered by two Argus as 10-c 240 hp. engines and has a top speed of 255-km. per hour. Long description. Les Ailes, February 13, 1936, page 3.

Focke-Wulf F.W.-58. Low-wing German monoplane for training in twin-engined and blind flying, radio, gunnery and bombing. Design and performance briefly described. Aero Digest, March 1936, page 66.

Dornier. Of the two Dornier ships illustrated, the Do-23 bomber is powered by two 750-hp. B. M. W. engines, carries a load of 3550 kg. and has a range of 1200 km. and a top speed of 260 km. per hour. The Do-18 seaplane for the Luft Hansa South Atlantic service, is powered by two "Jumo-205" 500 to 560 hp. Diesel engines. Five photographs only. Les Ailes, February 6, 1936, page 1.

The High-Speed Two-Engined Heinkel "He-111." The all-metal low-wing Luft Hansa monoplane described is used to transport ten passengers or a movable load of 2400 kg. at a cruising speed of 300 km. per hour when powered by two B. M. W. 660-hp engines. With two 880-hp. engines the cruising speed is 350 km. per hour. Les Ailes, January 30, 1936, page 3.

The Junkers Ju-86 Transport. A. Frachet. The ten-passenger Junkers transport described has a cruising speed of 350 km. per hour with two Pratt-Whitney Hornets and 300 km. per hour with two Junkers-Diesel "Jumo-205" 510/660-hp. engines. Les Ailes, February 27, 1936, page 3.

For Solo Training. Buecker Bue/33 German single-seater trainer climbs 3280 feet in three minutes and, powered with a 140-hp. Hirth engine, has a top speed of 142 m.p.h. Flight, February 27, 1936, page 230.

GREAT BRITAIN

A British Newcomer. Marendaz light monoplane designed to conform to the British Air Ministry aerobatic requirements. The plane has side-by-side seating and a top speed of 138 m.p.h. Brief illustrated description. Flight, February 27, 1936, page 237. Aeroplane, February 26, 1936, page 259.

Comfort on the Empire Routes. Accommodations of the new Short flying boats with sleeping berths for sixteen passengers, twenty-nine of which have been ordered for Imperial Airways. Design described and layout illustrated in sketch. Flight, March 5, 1936, page 258. Aeroplane, March 4, 1936, page 292.

The Empire Flying Boats. Structural innovations in the flying boats Short Brothers are building for Imperial Airways are described and illustrated, including wing, fuselage and tanks. Flight, February 20, 1936, page 202-a. Aeroplane, Febuary 19, 1936, page 233.

Great Britain. New fleet of 41 large planes ordered for Imperial Airways referred to with brief description of Armstrong-Whitworth and Short planes. Aero Digest, March 1936, page 66.

The Four Winds. Dimensions of the Hawker monoplane fighter F.36/34 which is powered by a Merlin "C" engine. Brief reference. Flight, February 6, 1936, page 140.

A New Recruit. The latest Avro Cadet type 643 MK II two-seater light training biplane described has a more powerful engine, an aeromatic C. of A. for a gross weight of 2000 lb., a maximum speed of 116 mph, and rate of climb at sea level of 700 ft/min. Flight, February 6, 1936, page 144.

Inside the Planking. Hull, wing, and engine-nacelle structure of the R. A. F. Vickers-Supermarine Scapa flying boat for reconnaissance, bombing and torpedo transport duties. Structural features are described in detail with drawings and photographs. Flight, February 27, 1936, page 220.

Learning in Luxury. Miles Nighthawk cabin monoplane built primarily for instrument and night-flying training. Method of "bagging" the pupil and layout of swing-over controls are illustrated and explained. Flight, February 20, 1936, page 202-c.

The Southampton Scapa. Internal arrangements and structure of the Supermarine flying boat for the Royal Air Force. It is suitable for reconnaissance, bombing, torpedo transport, or training and navigation instruction. The plane is powered with two Rolls Royce Kestrel 12-cylinder engines. Performance not given. Well illustrated description. Aeroplane, February 26, 1936, page 260.

The Three-Place Military Avro Ansom. The Coastal patrol and light bomber described is equipped with two 310-hp. Cheetah IX engines and has a range of 1250 km. and a cruising speed of 260 km. per hour. Les Ailes, February 20, 1936, page 3.

JAPAN

Flight without Engines in Japan. N. Matsumura. The Kijushu University type 7 glider is illustrated and gliding events in Japan in the last five years are briefly reviewed. Reference is made to the visit of Hirth and two German engineers to Japan for instructing Japanese pilots and technicians. L'Aerophile, January 1936, page 15.

U. S. A.

The New Cub Monoplane. New Taylor Cub J-2 high-wing two-place open or closed monoplane described shows constructional refinements in fuselage, landing gear, wings, and tail surfaces, as well as increased overall length and height. Aero Digest, March 1936, page 46.

The Roadable Autogiro. A road-drive mechanism permits the use of the new autogiro on roads when the propeller is disconnected. The rotor blades can be quickly folded and the machine driven on the road by means of power transmitted to the tail wheel. The direct take-off feature consists of a rotor-power drive with hydraulic locking mechanism. Description and sketch of internal arrangement. Aero Digest, March 1936, page 35. Aviation, March 1936, page 98.

Standard and Long Range Stinson Reliant Models SR7-A and SR7-B. Improved and faster versions of the 1935 Reliant model are said to be more economical to operate and have vacuum-operated flaps with slots which enable slower and steeper landing glides with less run. Detailed description with drawings illustrating special features of the design. Aero Digest, March 1936, page 42.

Two of a Kind. Waco Model D and the North American NA-16 light military general-purpose ships. Design, performance of both planes, and armament of the Waco are described. Flight, February 27, 1936, page 225.

U. S. S. R.

The Cheremetev M-1. The front wing is fixed but the rear wing is movable and performs the function of ailerons and elevators in the Russian light plane described. Brief description. Les Ailes, February 13, 1936, page 4.

Mock-Up. New large 60-passenger plane of the Maxine Gorki type being constructed in Russia are to be powered by 1250-hp. engines. Cabins and dimensions only referred to. Les Ailes, February 13, 1936, page 3.

Russia's Main-Line Train. Airplanes towing gliders will make trips between Moscow and Vladivostok in two days, on a passenger and freight service. One glider will carry storage batteries, lighting equipment, navigation instruments, and telephone connection with the airplane. Brief reference. Aeroplane, February 19, 1936, page 240.

The Soviet Light Airplanes. M. Precoul. Seven Russian light airplanes are illustrated in three views with a table giving the specifications for thirty-five planes of this type which have been produced in Russia since 1923. L'Aerophile, January 1936, page 15.

Airships

The New Zeppelin. Passenger accommodations of the LZ-129 designed for transatlantic service. Unusual drawings by Max Millar and photographs illustrate the chief features. Flight, March 5, 1936, pages 244 and 246.

Should Our Steamships be Changed to Airships. R. H. Upson. Advantages of the airship over steamships for transoceanic services. Cost and performance of the Macon are compared with those of a vessel on the water, the Macon with the Saratoga as an airplane carrier, and the airplane with the airship. U. S. Air Services, March 1936, page 15.

Aircraft Carriers

From Northern Waters. The new Swedish aircraft carrier "Gotland," described, is a warship of unusual interest. Eleven Hawker Osprey fighter-reconnaissance seaplanes are carried on a large platform in the after portion of the vessel and are launched by an unconventional catapult routine. Armament of the ship is also described. Flight, February 13, 1936, page 178-b.

The Maintenance of Seaplanes on the High Seas by Means of the Ship Hoisting Machine. A. Verdurand. Experimental results with movable cranes for hoisting seaplanes on board ships at sea. The investigation described was undertaken for the Compagne Generale Aéropostale which operates an air-transport service across the South Atlantic. The Kervarrec design of a movable crane for aircraft-maintenance ships, and the characteristics required of ships for this service are discussed in detail. L'Aeronautique, January 1936, page 3.

Rockets

The Four Winds. Liquid-fuel stratosphere-sounding rockets carrying instruments and equipped with parachutes are being experimented with in Russia. Brief reference. Flight, March 5, 1936, page 251

Patents

Collapsible Seaplane for Submarine (Mureaux). French Mureaux patent for a folding seaplane which can be rapidly folded up into a tubular hangar for accommodation on a submarine, and rapidly re-assembled for flight. Long description with six illustrations and reference to the fact that the French "Surcouf" will be the first submarine known to be equipped for seaplanes. The seaplane has a central float and side floats said to be similar to those of the catapultable planes of the U. S. Navy. Revue de l'Armee de l'Air, January 1936, page 106.

Metals

Use of Forgings in Modern Aircraft. P. N. Jansen. Introduction of aluminum and steel alloy forgings in place of built up fittings in Curtiss airplanes with reference to the inspection process. Aero Digest, March 1936, page 44.

Hammering down Production Costs. W. L. Lewis. The described drop-hammer method of producing metal stampings for airplane parts can be applied to the production of stampings in stainless steel as well as light alloys. Taken from Aviation. Aeroplane, February 12, 1936, page 201.

NON-FERROUS ALLOYS

Aluminum 1936 Practice. F. V. Hartman. Processes for heat treating, forging, extrusion, impact extrusion, spot welding, and machining aluminum. American Machinist, February 26, 1936, page 185.

Corrosion Protection for Aluminum Alloys. Advantages obtained with a new method of rolling punctured, instead of plain, aluminum foil on aluminum alloys used in aircraft construction for corrosion protection. This construction is lighter and coatings adhere better to the rough surface of the punctured alloy than to the plain. Brief reference. Automobiltechnische Zeitschrift, January 25, 1936, page 30.

Light Alloy Practice. H. G. Warrington. Discussions following presentation of the paper given in previous issues, and the author's reply. Welding and heat treating of duralumin are particularly dealt with. Metal Industry, February 7, 1936, page 187.

STEEL

Compression Tests of Stainless Steel Sections. E. W. Walker. The set of curves given for the determination of the stresses of various bent or drawn stainless-steel sections under compression loads were checked against skin-stringer-test data in the Air Corps Information Circular 697. It is concluded that if care is used in the selection of b/t and s/t the curves may be used for any skin stringer combination. Aero Digest, March 1936, page 32.

WELDING

Current Welding Literature. Title, author, and source of articles only are mentioned, including among other articles "Aircraft Constructional Welding" by R. F. Taylor. Welding Journal, February 1936, page 26.

Symposium on the Welding of Iron and Steel. British Iron and Steel Institute report which includes papers on the welding of aircraft structures by J. B. Johnson, J. Roosenschoon, H. Sutton and R. F. Taylor. Brief review. Royal Aeronautical Society Journal, February 1936, page 158.

Non-Metallic Materials

Reducing Resonance and Corrosion. Cellon Cerrex chromatic anti-corrosive undercoats and temporary protectives for use with the lighter alloys, particularly magnesium. Details given as well as those for a process for covering cabin panels to reduce resonance. Flight, February 20, 1936, page 215.

Surface Protection for Light Metals. F. Kolke. Short tests to determine the effect of new varnishes are dealt with in one abstract while the protection of light-metal surfaces by paints and lacquers are explained in a longer abstract with particular reference to the protection of aluminum and magnesium alloys used for aircraft and automobiles. Special attention is paid to the preliminary treatment of the surfaces. Translated abstracts from Farben-Chemiker, 1935, pages 18 and 325. Paint and Varnish Production Manager, March 1936, pages 32 and 35.

Stops Cracking. The Sokal Kalmite patented refractory paints described are painted or sprayed on the surfaces of the combustion space, such as the cylinder head, piston dome and valves, and set from the engine heat. The function of both coatings is to introduce selective cooling of the combustion chamber during periods of detonation when the temperature rises sufficiently to activate the coatings. Automotive Industries, February 15, 1936, page 227.

Stress Analysis and Structures

Calculation of Compression Beams Elastically Supported at their Ends. H. Riviere. Calculations are given for the straight beam, the extremities of which are elastically supported, and for the buckling of web members which are rigidly assembled. L'Aeronautique, L'Aero-technique Supplement, January 1936, page 7.

Graphical Solution of Continuous Beams under Combined Loading. J. M. Jacobson. Conjugate point construction, graphical solution of precise equations, and construction of precise moment curves for each span, are considered. Aero Digest, March 1936, page 29.

Testing of Materials

Industrial X-Ray Practice. R. C. Woods. Present-day uses of x-rays in production testing, inspection, and industrial research, together with practical information on the necessary equipment and the cost of its installation. Electronics, February 1936, page 7.

Engine Design and Research

Aircraft Engine Sessions. Discussions only of the Allen, Young, Taylor, Hamilton and Veal papers which appeared in previous issues. S. A. E. Journal, March 1936, page 39.

Aluminum Heads at Paris Show. Properties and casting difficulties of Alpax aluminum alloy for automobile cylinder heads, the British method of casting, and the preference for silicon-aluminum alloys. Abstract from Revue de l'Aluminum, November 1935. Automotive Industries, February 29, 1936, page 349.

Engine Starters. Comparison of various types of electric and inertia starters. Les Ailes, February 13, 1936, page 5.

Flow of Different Fuels through Carburetor Jets. R. Hase. Change of fuel without interchange of carburetor jet will lead to a varied fuel consumption, as verified by the tests described. It was determined that the fuel quantity flowing through the jet depends principally on the vacuum and on the specific weight of the fuel. Methods for correcting unavoidable errors are given and from the tests a flow coefficient is found for the carburetor jet. Automobiltechnische Zeitschrift, February 15, 1936, page 58.

Development Trends in Carburetor Construction. M. Preuss. Design of carburetors for airplane engines and motor vehicles. The problems discussed include atomization, mixture ratio and feeding, fundamentals of carburetion, carburetors with acceleration pumps, auxiliary equipment for starting, development of the carburetor as adjuster of r.p.m., carburetor economy, and the design of carburetors unaffected by position and dynamic forces. V. D. I., February 15, 1936, page 175.

In the Domain of Tests at Villacoublay. Tests of an exhaust-gas silencer, an automatic altimetric corrector, and an arrangement for heating the cabin are being carried out on the Amiot 143 and tests of the elastic suspension of engines on the Bloch-200. Cooling difficulties with the Morane 405 pursuit ship are also being investigated. Very brief references only. Les Ailes, February 27, 1936, page 3.

Pressure Under Top Piston Ring Major Cause of Cylinder Wear. O. Halling. Provisions in design necessary to reduce cylinder wear, and observations on engines operating under varying conditions. Automotive Industries, March 7, 1936, page 370.

A Promising Power Plant. Coventry Victor flat four-cylinder double-opposed horizontal engine is designed to fit into wings of a light airplane and to give 40/45 hp. for 120-lb. weight. Drawings illustrate the design of the Neptune motor-boat engine from which the aircraft model is being developed, and the Neptune design is discussed. Aeroplane, March 4, 1936, page 291.

Recent Developments in Light Alloy Pistons. H. J. Mabrey. Selection of suitable light alloys for pistons. Brief abstract from Journal of the Institution of Production Engineers, September 1935, page 495. Mechanical Engineering, March 1936, page 182.

A Rotative Single-Cylinder Engine. Two pistons operate in a single horizontal cylinder with partial precompression in the crankcase in the two-cycle Richard engine described. The design is said to reduce the cross-section of the engine to the bore of the cylinder. Les Ailes, February 20, 1936, page 4.

Sparking Plugs with Platinum Points. A very much reduced burning and a great reduction in working voltage were among the research results obtained with the K. L. G. sparking plugs. Brief description. Engineer, February 21, 1936, page 211.

Torsional Oscillation of Shafts. J. L. Beilschmidt. Formulas are developed for analyzing harmonic elastic distortion due to force couples which act at different points on a crankshaft, including moments due to inertia masses. Aircraft Engineering, March 1936, page 79.

Cooling Problems, with Particular Reference to the Work of the 24-Foot R. A. E. Tunnel. G. P. Douglas. Design of an efficient duct system for an airplane engine, in which the speed of the cooling air is reduced to that required for efficient cooling and is discharged again without spoiling the flow around the aircraft. The test results discussed were obtained with the Gauntlet airplane fitted with a radial air-cooled Mercury VIS engine having a simple ring cowl, and with a Bulldog fitted with a Rapier air-cooled in-line engine. The first part of the article deals with the tunnel in which the investigation took place. Royal Aeronautical Society Journal, February 1936, page 102.

D. K. W. Two-Stroke Engine. The test results discussed were obtained in an investigation with a small two-cycle engine to analyze the reverse-flow scavenging adopted, for comparison with another engine of the same make with conventional cross-flow scavenging. Automobile Engineer, February 1936, page 70.

Design of Ports and Valves for Aircraft Engines. C. F. Taylor. Effect of valve size, and of valve and port design on actual engine performance. One of the M. I. T. investigations described was undertaken to determine whether a considerable reduction in port area could be made without serious decrease in the orifice coefficient of the valve and port together. Research on exhaust-valve size indicated that a remarkable amount of reduction in exhaust-valve area was possible without serious effect on engine power. Apparatus, test procedure and results are discussed. Journal of the Aeronautical Sciences, February 1936, page 132.

An Engine with Oscillating Vanes. In place of the usual type of piston, the Ponchaux engine described is provided with oscillating vanes, while the engine parts are grouped symmetrically and concentrically around a single crankshaft so that the forces are transmitted by connecting rods similar to those of the radial engine. A lighter, smaller and more powerful engine is claimed for the design. Two good illustrations but unsatisfactory description. Les Ailes, February 6, 1936, page 5.

Harmonic Analysis of Engine Torque Due to Gas Pressure. E. S. Taylor and E. W. Morris. In the investigation of engine torque due to gas pressure, the conclusion is reached that the torsional "roughness" of a normal engine will be approximately inversely proportional to the square of the number of cylinders (for more than six cylinders). Curves are given for harmonic coefficients versus throttle setting, spark advance, compression ratio, and mixture ratio. Results of this research at M. I. T. are discussed in detail. Journal of the Aeronautical Sciences, February 1936, page 129.

Infra-Red Radiations from Otto-Cycle Engine Explosions. S. Steele, A. Wharton and C. H. Roeder. The research described was part of the general investigation of combustion in an engine cylinder conducted at the Bureau of Standards with the financial assistance of the N. A. C. A. Engineering, January 31, 1936, page 131.

Lincoln Zephyr Thin-Wall Steel Pistons. The new Lincoln-Zephyr piston described is cast in high copper bearing alloy steel in sections so fine that the weight of the piston is substantially the same as it would be in aluminum. Performance of the steel and aluminum pistons compared. Motor Age, February 1936, page 36.

Military Aircraft Engines of the Future. F. L. Prescott. Ratings of 1000 to 1200 hp., 12 to 14 cylinders, dual propellers and probably fuel injection are predicted for military aircraft engines of the immediate future. While 1500 to 2000 hp. per engine and 18 to 24 cylinders will be required of the engine of the more remote future. Possible lines of improvements in present-day engines are pointed out and indicator cards are illustrated and discussed which show that it will be possible greatly to increase the output per cubic inch by high supercharging pressures, provided improvement in fuels and spark plugs is sufficiently advanced. Mechanical Engineering, March 1936, page 157.

Relation of Exhaust-Gas Composition to Air-Fuel Ratio. G. A. D'Alleva and W. G. Lovell. In the research reported, complete exhaust gas-analyses for carbon dioxide, carbon monoxide, hydrogen, methane and oxygen have been related to directly measured air-fuel ratio for three engines over a range of operating conditions and with varied air-measuring equipment. The data are consistent and indicate that exhaust-gas composition is related to measured and also to computed air-fuel ratios with a deviation of about 3 per cent. Discussion of the paper by H. C. Dickinson, E. Bartholomew, H. C. Gerrish and F. Voss is included. S. A. E. Journal Transactions, March 1936, page 90.

A Survey of Engine Development. Arthur Nutt. Introduction of the dynamic damper, trend toward double-row radials, continued development of liquid-cooled engines, development of automatic control devices, increased development of higher octane number fuels, decrease in fuel consumption, and continued predominance of the single-row radial in the field below 1,000 hp. are included among the outstanding trends in aircraft-engine design discussed. The possibility of engines totally enclosed within the wing structure and the development of liquid-cooled engines for this purpose are considered by C. F. Taylor in the discussion following the paper. P. B. Taylor makes further predictions. Journal of the Aeronautical Sciences, February 1936, page 137.

BEARINGS

The Loading and Friction of Thrust and Journal Bearings with Perfect Lubrication. H. A. S. Howarth. Discussion following presentation of paper published in the May issue. A. S. M. E. Transactions, February 1936, page 122.

White Metal and Bronze Bearings from the Manufacturer's Point of View. M. Melhuish. Factors of importance in the production of finished bearings. Effects of impurities and methods of alloying tin-base bearing alloys, die-cast bearings, lined and steel-backed bearings, lead bronze bearings, disadvantages of copper-lead bearings, lead and zinc-base alloys, connecting-rod bearings, aluminum-alloy connecting rods, bearing failures, and bronze bearings are considered. Long abstract of paper presented before the Institution of Automobile Engineers. Metal Industry, February 14, 1936, page 209.

VIBRATION

Eliminating Crankshaft Torsional Vibration in Radial Aircraft Engines. E. S. Taylor. Elastic and inertia characteristics of the crankshaft-propeller combination of a radial aircraft engine are represented mathematically and the torque given in the form of a Fourier's series for predicting the behavior of the crankshaft in torsional vibration. Limitations in previous designs of vibration dampers are pointed out and the development of the pendulum type of vibration absorber for the Wright Cyclone engine is described. S. A. E. Journal Transactions, March 1936, page 81.

Transient Torsional Vibrations. W. A. Tuplin. Stresses associated with transient torsional vibrations in an internal combustion engine. A dynamical system is described which consists of two heavy rotors connected by a single shaft. A drive which gives critical speeds of low order below the running range can be represented by such a system and the transient vibration stress figures obtained are said to be reasonably accurate. Formulas for calculating the vibration stresses and a method for determining the maximum amplitude of vibration attained in accelerating past a critical speed are given. (To be continued.) Engineering, February 7, 1936, page 154.

Transient Torsional Vibrations. W. A. Tuplin. Typical examples are given in the concluding article. Engineering, February 28, 1936, page 221.

DIESELS

Advantages of Supercharging Diesel Engines Besides Power. O. Thornicraft. Important advantages in supercharging, besides the increase in power, were determined in the tests and results described. Abstract from I. A. E. Journal, December 1935. Automotive Industries, February 29, 1936, page 348.

Compression Losses in Smaller Two-Stroke-Cycle Diesel Engines. J. Zeman. Losses of gas during compression and processes taking place when the ports are closed by the piston. Original article gives the calculations of the compression ratios necessary for this type of engine, taking into account the compression losses. Brief abstract from Forschung auf dem Gobiete des Ingenieurwosens, May-June 1935, page 129. Mechanical Engineering, March 1936, page 181.

Diesel Motors. No aircraft with compression-ignition engines are at present in R. A. F. service but four of different types have been equipped for experimental purposes. Brief reference only. Aeroplane, February 26, 1936, page 254.

Flame Photographs from Diesel Tests. O. Holfelder. The flame photographs illustrated and discussed were taken in the machine laboratory tests at the Dresden Technical High School. A diagram of the test arrangement, and time exposures of fuel injection, ignition and combustion are included. V. D. I., February 15, 1936, page 193.

Engines

The Double-Row Niagara. With cylinders arranged in parallel pairs with a common helmet over each for the valve gear, the new Pobjoy Niagara develops about 173 hp. for weight of about 270 pounds. Brief reference. Aeroplane, February 26, 1936, page 274.

American Airplane Engines. Specifications for airplane engines are given in two tables, one devoted to those produced by sixteen American manufacturers, and the other to foreign makes. Brief discussion of trends indicated in the tables is also included. A third table covers automotive Diesels and other heavy-oil engines, produced in the United States, England, France, Germany, Italy, Sweden and Switzerland. Automotive Industries, February 22, 1936, page 290.

For Cheaper Flying. The 3.6-liter in-line Cirrus Minor aircraft engine and results of the British Air Ministry type test are described. The engine develops a maximum of 90 hp. at 2600 r.p.m., has a fuel consumption of 3½ to 4 gallons per hour and oil consumption of 1 to 1½ pints per hour, and weighs 195 lb. Aeroplane, February 12, 1936, page 205.

Radial Air-Cooled Engine. The new automobile engine for a racing car, built by Monaco and Aymini for Count Trossi, has eight double cylinders, operates on the two-stroke cycle, and has a common combustion chamber for each pair of cylinders. Brief description. Automobile Engineer, February 1936, page 70.

An Unusual Two-Stroke. The German F.1200 Schliha 23-hp. engine for ultra-light aircraft has an unconventional gas-transfer system. It is a flat-twin-cylinder two-stroke engine developing a maximum power of 36 hp. at 3100 r.p.m. and weighing 75.8 lb. Each piston carries on its crown a tubular extension projecting into a corresponding extension of the cylinder head. As the pistons descend in the cylinders, the gas is compressed in the crankcase and passes through the interior of the pistons into the extension tubes. Flight, February 13, 1936, page 178d.

Engines for Light Airplanes. Engines for the Pou-du-Ciel. The Aubier and Dunne and the English Scott "Flying Squirrel" are described and compared to the Ford V-8 engine. The first is a 2-cylinder 2-cycle 17-hp. engine having a scavenging pump and weighing 38 kg. The Flying Squirrel is said to be a stronger 2-cylinder engine weighing 40 kg. and developing 34 hp. at 5200 r.p.m. Automobiltechnische Zeitschrift, February 15, 1936, page 70.

For the Light Brigade. In the air-cooled flat-twin light 36-hp. airplane engine of the Altar Car and Engineering Company, the cylinders are slightly offset to allow for a two-throw crankshaft, and the outer Elektron crankcase cover is streamlined. Description but no illustrations. Flight, February 27, 1936, page 233.

The Jacobs 285-hp. L-5 and L-5M Engines. The new 7-cylinder radial air-cooled engines described are rated at 285-hp. at 2000 r.p.m. at sea level. The L-5 has dual battery ignition, and the L-5M dual magneto ignition. Aero Digest, March 1936, page 36.

New Aeronca Two-Cylinder Engine Gets Department of Commerce Approval. The E-113C two-cylinder opposed aircraft engine described develops 40 hp. at 2500 r.p.m. and weighs 121 pounds. Automotive Industries, February 29, 1936, page 345.

A New German Diesel Airplane Engine for Regular Service. W. Zuerl. The Mercedes-Benz type "OF2" 4-cycle 12-cylinder V-form Diesel engine described develops 750 hp. at 1750 r.p.m. and is said to be a high-performance engine for long-distance commercial air services. Cold starting is facilitated by means of a compressed-air starter and a 2-volt hot bulb. Weight with accessories but without the propeller hub is 935 kg. or 1.17 kg./hp. Description and performance curve. Automobiltechnische Zeitschrift, February 15, 1936, page 69.

New Italian Engines. Fiat A-33 RC, Isotta Fraschini Astro 7C-40, Alfa Romeo 110-1 and 115-1, and Piaggio PX1RC-50. Very brief reference to cylinders and power developed. Les Ailes, February 13, 1936, page 5.

New Lorraine Engines. Brief reference to three new engines which are to be brought out. Les Ailes, February 27, 1936, page 4.

Potez Engines. Mounted entirely within the wing, the Potez 111 12-cylinder flat air-cooled 450 hp. engines are designed for the "63" attack planes. Brief reference only. Les Ailes, February 27, 1936, page 5.

Youngest of the Cirrus Family. The Cirrus Minor 82-hp. airplane engine has a fuel consumption of 3½ to 4 gal. per hour at normal r.p.m. and a compression ratio of 5.8 to 1. Main alterations over the previous model are described with power curves obtained in Air Ministry tests. Flight, February 20, 1936, page 201.

Engine Testing

Engine Test Equipment (J. Pettitt-Herriott). British-Air-Ministry requirements governing aircraft-engine testing with descriptions of the design, operation and maintenance of some testing apparatus in use at the present time, including the Froude DPX dynamometer, Heenan and Froude wind tunnel for engine testing, Amal flowmeter, rotameters, altitude-test equipment, Ashdown rotoscope, Dobbie-McInnes Farnborough indicator, Cambridge surface thermocouple and Foster patent plug couple. Aircraft Engineering, March 1936, page 61.

Sounding for Sounds. "Capac Bin-Aural" testing equipment for detecting noises indicating defects in engines. Brief description of equipment used in British aircraft-engine shops. Flight, March 5, 1936, page 250.

Fuels and Lubricants

Lubricating Oils Studied to Determine Effects on Cylinder and Ring Wear. C. M. Larson, W. G. Ainsley and M. Fairlie. Effect of oil characteristics on cylinder wear and ring sticking tendencies of automobile, bus and aircraft engines. Wear caused by abrasive materials, cylinder surface finish, piston finish and hardness, ring design and pressure, and cylinder distortion are also discussed. Flight-test results for twelve 420 hp. nine-cylinder air-cooled engines using 80 octane leaded fuels are given. It was found that low oil consumption seemed to be related to freedom of ring sticking. Reference is made to laboratory equipment designed for studying the ring wear in aircraft-engine cylinders. Abstract of paper presented before the S. A. E. Oil and Gas Journal, February 13, 1936, page 24.

Oil and National Defense. B. T. Brooks and L. C. Snider. Some aspects of the petroleum shortage in the United States with the prediction that the shortage of domestic petroleum production may be expected in five to eight years. It is recommended that the manufacture of petroleum substitutes be built up to supplement the oil supply as domestic production decreases. Army Ordnance, January-February 1936, page 217.

Army Approval. Air Corps adoption of DuPrene as standard for lining oil and fuel line and engine-radiator connections. Brief reference. Aero Digest, March 1936, page 52.

Diesel Engine and Fuels and Lubricants Session. Discussions only of the Schweitzer and Hetzel, Rendell and MacGregor papers appearing in previous issues. S. A. E. Journal, March 1936, page 29.

Fuels and Lubricants. Discussions only of the D'Alleva, Lovell, and Sweigert papers appearing in previous issues. S. A. E. Journal, March 1936, page 37.

Time-Saving Lubricator. Alemite "Rock-Crusher" HR-32 electric lubrication power gun used by T.W.A. Brief description. Aero Digest, March 1936, page 48.

Petroleum Shortage and Its Alleviation. L. C. Snider and B. T. Brooks. Possibility of a petroleum shortage in the United States. The results already obtained by chemical engineers and researchers towards producing petroleum-like products from other sources are considered and changes predicted which are likely to occur in the petroleum industry and in the utilization of petroleum products. Journal of the American Society of Naval Engineers, February 1936, page 91.

Synthetic Lubricants. The production of "Kogasin," a synthetic lubricant, the characteristics of which are said to be fully equal to those of Pennsylvania oil. General discussion. V. D. I., January 11, 1936, page 49.

Propellers

Brakes for Airplanes. Need of brakes for stopping the propeller simultaneously with the engine is discussed with reference to the device developed by R. B. Quick which has been used on the Sikorsky S-42 Clipper ship. Scientific American, March 1936, page 148.

Change-Speed Gears for Aero-Motors. H. C. Watts. Detachable wooden propeller blades and standardized hubs are recommended and the effective application demonstrated of a two-speed gear box between the engine and a constant-speed variable-pitch propeller for airplane speeds up to 400 m.p.h. Curves indicate how nearly this combination approaches the ideal for the unsupercharged engine and also that the gear box becomes less useful with increase of supercharge height. In the discussion following, (carried over to the February 12 issue, page 203), reference is made to the report that the DeHavilland Company are experimenting with Hamilton propeller hubs fitted with detachable blade of laminated plastic or synthetic resin material. Abstract of paper presented before the Royal Aeronautical Society. Aeroplane, February 5, 1936, page 183. Editorial comment, page 137, abstract of paper and discussion. Flight, February 6, 1936, page 159.

Airscrew Development. H. C. Watts. Adaptation of the two-speed gear box, located between the engine and a constant-speed variable-pitch propeller, to non-supercharged and supercharged engines. Concluding sections of paper presented before the Royal Aeronautical Society. Flight, Aircraft Engineer Supplement, February 27, 1936, page 13.

The British Industries Fair at Birmingham. Avery airplane-propeller balancing machine. Design illustrated and method of operation described. Engineering, February 28, 1936, page 226.

Investigations on the Origin of the Sounds Emitted by Revolving Airscrews. J. Obata and U. Yosida. Further studies on the pressure variations in the neighborhood of the propeller blade. Results of tests only in a brief abstract of the Tokio Imperial University, Aeronautical Research Institute, Report No. 132, December 1935. Aircraft Engineering, March 1936, page 87.

A New Variable-Pitch Propeller. Blades of the Poulet automatic variable-pitch propeller have a helicoidal motion of rotation around their axis controlled by centrifugal force, and rotation on the hub, around the engine axis, controlled by the resisting couple. Design and method for inversion of pitch to produce a braking force are described. Les Ailes, February 27, 1936, page 4.

The Propeller with Slots. The Holman propeller with the Handley-Page type of slot is designed to reduce airplane noise at its source and to improve the efficiency over that of the classical propeller. Brief description of American invention. Les Ailes, February 20, 1936, page 4.

Research on Model Airscrews. G. P. Douglas. Question of high propeller-tip speeds and results obtained from model propeller tests in England. Uses for these propellers and an investigation of noise associated with high tip speeds are also discussed, as well as variation of drag coefficient and of thrust with tip speeds, ideal shape for high speeds, scale effect, and the type of blade section necessary to minimize loss at high speeds. Paper presented before the Volta Congress. Aircraft Engineering, March 1936, page 73.

Ratier's Latest. The propeller illustrated has a hollow center to allow the passage of "moteur canon" shells, and a small windmill operating the pitch-changing mechanism. Photograph only. (Description from Les Ailes, referred to in March 1 issue of Digest.) Flight, February 27, 1936, page 233.

Tables for Use in an Improved Method of Airscrew-Strip-Theory Calculation. C. N. H. Lock and D. Yeatman. Abstract refers to formulas and tables given in the original article to calculate the performance of any propeller below the stalling angle provided suitable airfoil data are available. From British Aeronautical Research Committee Reports and Memoranda No. 1674. Aero Digest, March 1936, page 38.

Compromises in Propeller Design. D. Biermann. Compromise in propeller design is defined as the improvement in propulsive efficiency for the take-off and climb conditions at the expense of efficiency at high speed. The author explains the operating characteristics of various compromise designs, the effect of various amounts of compromise on the power available for certain conditions, and the mean reduction in critical altitude high-speed pitch which was made necessary by the sea-level operation of supercharged engines. Journal of the Aeronautical Sciences, February 1936, page 142.

Acoustics

Reducing Resonance and Corrosion. Metal panels coated with fibrous particles of cotton, silk, or wool are being used in cabins of transport planes as a means towards reducing noises in the cabin. The exact nature of the fiber to be applied depends on the type of surface to be treated. The Michel and Marchal process has been applied to the Breguet 393's. Method of application is given, as well as details of the Cellon Cerrex anti-corrosive undercoats and temporary protectives for use with light alloys, particularly magnesium. Flight, February 20, 1936, page 215.

The Invisibility. Necessity for reducing the noise of airplanes, with brief reference to a DVL laboratory in Berlin which is especially designed for noise-reduction tests. Les Ailes, February 6, 1936, page 4.

Airport Equipment

The Airport Exhibition. British airport equipment shown at the exhibit held in connection with the British Conference of Aerodrome Owners. Aeroplane, February 5, 1936, page 167. Flight, February 6, 1936, page 156.

Armament

Flying Artillery. Heavier aircraft guns than hitherto believed possible are feasible according to the mathematical report of A. Klemin and B. Ruffner, which was made for the American Armament Corporation. The report showed that unexpected stability may be looked for in airplanes used as gun platforms. A 250-lb. gun has been designed which fires a 1-lb. shell 4400 yards at an elevation of 45 degrees. Brief abstract of this and of the de Florez paper on "mechanical ears for piloting a plane by sound alone," which were presented before the Institute of the Aeronautical Sciences. U. S. Naval Institute Proceedings, March 1936, page 445.

Instruments

Improvements to Gyroscopic Devices, Especially to those Used as Vertical Indicators. Indicator of the Position and Motion of Airplanes. C. de Haya. Abstracts of French patents. L'Aeronautique, L'Aerotechnique Supplement, January 1936, page 12.

Behind the Gyorizon. Combination of a normal rate-of-turn indicator with a visible horizon consisting of a colored liquid tested to remain liquid down to —60° C. Design and use in blind flying described and illustrated. Flight, February 27, 1935, page 235.

The Physical Society's Exhibition. The Hughes echo sounders with rotating-arm recorder, used in aerial navigation, the Negretti and Zambra fuel-pressure gage, an air-flow recorded, portable sensitive vibration recorder, and other instruments are described. Engineering, February 7, 1936, page 160.

Manometer Errors Due to Capillarity. R. G. Folsom. Data required for the selection of manometer tube size when making measurements within a given limit of error. Results of an investigation described. Instruments, February 1936, page 36.

Measurement of Aircraft Vibration During Flight. C. S. Draper and G. P. Bentley. The equipment developed for measuring aircraft vibration consists of a pick-up unit for converting mechanical motion into electrical voltage variations which are recorded photographically as displacement-time records by means of a vacuum-tube integrating amplifier and an electro-magnetic oscillograph. Component parts of the instrument and its calibration are described. The sample records and test results presented were obtained in the joint instrument development program for the study of aircraft and engine vibration undertaken by M. I. T. and the Bureau of Aeronautics. Journal of the Aeronautical Sciences, February 1936, page 116.

Miscellaneous Equipment

Accumulators for Aeroplanes. Trends in accumulator design for aviation purposes in the past twenty years, and description of the characteristics of the new Dagnite designed particularly for ease of maintenance. Aircraft Engineering, March 1936, page 81.

Air Conditioning Transports. Caldwell and Associates air-conditioning device developed in conjunction with T. W. A. for Douglas DC-2's. Few details. Aero Digest, March 1936, page 48.

Engine Fire Extinguisher. The Kidde Lux fire-extinguishing system described is adapted to engine protection either in flight or on the

ground and makes use of the slipstream instead of fighting it. Brief description. Aero Digest, March 1936, page 48.

Maintenance of Electrical Equipment. W. E. Crook. Adjustment of shunt dynamos by three methods, testing of generators after assembly, repair or overhaul, and fault tracing in electrical apparatus. Conclusion of article on maintenance for a ground engineer's British X electrical license. Aircraft Engineering, March 1936, page 68.

Parachutes

Parachutes for the Flying Personnel. A. Paricaud. Special requirements of parachutes for pilots of high-speed and training airplanes are discussed and the Lemercier 200, Aerazur A. I. 30, Aviorex 111 and 112, Gravereaux 540, Ors T. 10, Beyne (Harness), S. G. P. 400 and 300 and the Vinay 505 parachutes are described. Continuation of article. L'Aeronautique, January 1936, page 13.

Physiology and Practice of Parachute Jumping. M. M. Gordoi, M. S. Isarff and Evdokomoff. Soviet experimental results in training parachute jumpers, and the physiological effects of the parachute descent on the jumper. Included is a brief account of a parachute jump from an altitude of 8100 meters with the opening of the parachute delayed until within 200 meters of the ground. Three articles, the first of which describes a rotating machine for training parachute jumpers and the influence of the jump on the neuro-psychic centers. Revue de l'Armee de l'Air, January 1936, page 58.

Photography

Aerial Photography. B. B. Talley. The technique of getting good photographs from the air, the necessary cooperation between the pilot and the photographer, and applications of various types of cameras are discussed. Recommendations are given regarding films, exposure time, lens and shutter speeds, filters and development time. The K-10, K-3B, T-3A and the Zeiss four-couple cameras are described. Mechanical Engineering, March 1936, page 151.

Use of Cinematography in Aircraft Flight Testing. F. R. Collbohm. Motion pictures applied to testing aircraft in flight, with particular explanations of their use in diving tests, water take-off, landing speed and load-deflection tests in flight. Journal of the Society of Motion Picture Engineers, March 1936, page 223.

Radio

Blind Approaches in England. The Lorenz blind-landing system demonstrated in England. Brief illustrated description. Flight, February 27, 1936, page 240.

New Radio Equipment. A special feature of the AC.45 and AC.46 aircraft radio installations is the remote control system, entirely electrical, whereby backlash is said to be eliminated. Very brief reference only. Aeroplane, March 4, 1936, page 305.

Pea-Soup Parking. Ground installation of the Lorenz blind approach system recently tested in England. Brief description. Aeroplane, March 4, 1936, page 303.

Problem of a Radio for the Private Flier. Questions regarding the type of radio to be designed for the private flier, which were submitted to the French Air Ministry by the Syndicate Professional des Radio-electriciens, are given with discussion. Les Ailes, February 27, 1936, page 767.

Steinhoff Course Indicator. The simplified radio-navigation instrument described is said to have possibilities as a controlling device in maneuvers, by enabling planes flying in formation through fog or smoke screen, to maintain positions relative to a leading plane equipped with a transmitter. The device operates as a course indicator in either of two ways, and as a position indicator in conjunction with a magnetic or gyro compass. Aero Digest, March 1936, page 49.

Switzerland Non-Stop. H. A. Taylor. The Sperry automatic pilot and the Lorenz system of blind approaches, employed by Swissair in the Alps. Description of their operation. Flight, February 20, 1936, page 192.

Antennas for Air Navigation. D. G. Fink. Data on the broadcast signals used by aircraft pilots for radio-compass direction finding. The table lists broadcast stations suitable for aeronautical direction finding giving the antenna location, call, frequency, power, and interference. Electronics, February 1936, page 34.

Blind Approaches at Farnborough. Equipment for two special Monospar 25S planes for experiments in radio blind approach, to be made at Farnborough. Brief reference. Flight, February 6, 1936, pages 147 and 150.

Homing Signal. Demand for a method of using waves from commercial broadcasting antennae for the radio guidance of pilots. Firms developing the "homing type" compasses are given with the statement that the Air Corps is at work on similar apparatus. Brief reference. Business Week, February 15, 1936, page 24.

Methods of Landing by Radio Guidance in the United States. Tests of the landing-beam system of the Bureau of Standards and the radio-compass system of the Air Corps. French translation of article appearing in Aviation, August 1935. Revue de l'Armee de l'Air, January 1936, page 88.

Radio Communications on Board Pursuit Ships. P. Alexandre. Solutions to problems in radio telephone communication on pursuit ships with illustrations of some experimental tubes used for short waves. L'Aerophile, January 1936, page 19.

Radio Meteorography. Radio equipment developed for use in sounding balloons by C. F. Brooks at the Blue Hill Observatory. Brief description. Scientific American, March 1936, page 147.

Wireless and the Aerodrome Owner. R. P. G. Denman. Limitations of radio for aviation and congestion on the wave lengths used. Three radio methods by which an airplane may determine its bearing in relation to a ground station are given and the installation for blind landing at Heston is described. Two-way communications between pilot and airport control is taken up with a brief reference to television. Discussion following presentation of the paper at the British Conference of Aerodrome Owners is also given. Aeroplane, February 5, 1936, page 159. Flight, February 6, 1936, page 161.

Television

Patent Claims Television Can Land Plane in Fog (John Hays Hammond, Jr.). Picture of the landing field is transmitted to the pilot simultaneously with data of the exact position of his plane over it, direction of his flight, his altitude, and the wind velocity and direction, according to the television apparatus described. Science News Letter, March 7, 1936, page 158.

Navigation

Piloting Commercial Aircraft. H. G. Brackley. Problems the present-day captain has to tackle on every-day all-the-year-round flying to Europe, Africa, India and Australia. Controllability of aircraft, control-cabin comfort, and instrument-board layout are taken up. The method of piloting marine aircraft in the Mediterranean and difficulties encountered on the various Indian and Australian routes are described. Royal Aeronautical Society Journal, February 1936, page 85 and discussion page 94.

Meteorology

The Disturbances Due to the Ground Profile and Aviation. M. Baldit. Disturbances affecting the airplane flying over forests, lakes, marshes, industrial regions, hills, mountains, valleys, and in passing from land to sea and vice versa. Abstracted from La Meteorologie, June 1935. Revue de l'Armee de l'Air, January 1936, page 100.

Systematic Reporting of Weather from Airplanes in Flight. O. T. Larson. Plane-to-ground weather reporting procedure followed by pilots of United Air Lines. Airplane reports from all airlines operating into a station are cleared through the airport Weather Bureau offices and are made available for checking and distribution. Bulletin of the American Meteorological Society, January 1936, page 12.

Large Scale Storms. W. H. Wenstrom. Typical fronts and cyclones of the north temperate latitudes, and the general patterns on which large-scale temperate-zone storms are formed. Tropical disturbances sometimes appearing in the southeastern states are also considered. Second of a series on Flying Weather. Aero Digest, March 1936, page 20.

Ice Formation in Air Travel. H. Noth and W. Polte. Viewpoints of the meteorologist and pilot on ice-formation problems. Brief abstract from Luftwissen, November 1935. Aero Digest, March 1936, page 39.

Air Forces

FRANCE

Formation of a Corps of Navigators. Commandant Andre Langeron. Training of 3500 recruits per year as pilot-navigators is suggested in order to provide France with a reserve corps of navigators who would be able to pilot by day or night, airplanes flying at more than 400 km. per hour, to assume the duties of either pilot or navigator, and to excel in bombing and firing guns. Requirements for a navigator in 1940 are described. Les Ailes, February 6, 1936, page 6.

GREAT BRITAIN

According to Plan. Progress of the Royal Air Force expansion scheme to date and the response of the aircraft industry. Airplane orders may be given for types already in production but equipped with more powerful engines, for types straight off the drawing boards before a prototype is produced, and for service machines converted from civil aircraft. In regard to personnel expansion, the innovation has been made of engaging men direct from civil life for training as airmen pilots. Methods of training and the provision of increased facilities are taken up as well as the enlistment of tradesmen and aircraft hands. Photographs include the Gloster Gladiator fighter, Hawker Hind light bomber, Vickers Wellesley medium bomber, and the prototype Bristol 142 from which a medium bomber is being developed. Flight, February 6, 1936, page 149.

Matters of Moment—About this Armament Business. The British government's method for financing re-armament, the amalgamation of military aircraft firms, and the "eternal war between the three branches of the Services for the largest appropriations," are discussed. Aeroplane, February 5, 1936, page 147.

A Survey of Aeronautical Progress. Efforts being made at present to restore the British air strength to a level of safety, or supposed safety, are criticized in an editorial. The author points out that the final British predominance in the World War was secured by the overwhelming number of aircraft thrown into the contest, and that, in the next war, numbers of aircraft alone will decide the issue. He criticizes the British program of expansion which calls for an output equal to one-twenty-fourth of the rate actually reached in 1918. Engineer, February 7, 1936, page 153.

SOUTH AFRICA

The Defense of South Africa. Program for modernizing the South African Air Force. Aeroplane, February 21, 1936, page 212.

U. S. A.

Aeronautical Activities of the U. S. Coast Guard. Development of aeronautical activities in the Coast Guard with photographs of the Acamar, Sirius, and Arcturus as well as of the Liore et Olivier H. 197 French ambulance plane. Brief article. Revue de l'Armee de l'Air, January 1936, page 83.

The Five Year Program. Editorial comment on General MacArthur's proposed five-year program of procurement, with brief reference to procurement program for the Air Corps. Army Ordnance, January-February 1936, page 237.

Florida Air Force Maneuvers. Review of Florida concentration and maneuvers of the G. H. Q. Air Force during December, 1935. Army Ordnance, January-February 1936, page 243.

Our Defense Needs. Brigadier General J. R. Delafield. Sources of danger to the United States, means available for defense, and the ability of the present Army, Navy and Air Services to meet these requirements. Lack of enough well-trained officers and non-commissioned officers, no adequate supplies of modern munitions, and no means to produce them quickly enough in sufficient quantities are said to be the great weaknesses making our plan of national defense, as now carried out, largely ineffective. Army Ordnance, January-February 1936, page 225.

Woes of Prosperity. Douglas contract for 114 torpedo-bombers to be used on two new aircraft carriers, the Consolidated and Northrup Army orders, and the shortage of labor for airplane construction are briefly discussed. Business Week, February 22, 1936, page 44.

Mid-Winter Tests. February maneuvers conducted as cold-weather service test of aircraft equipment are briefly outlined with photographs of engine heating tent and ski equipment. Aero Digest, March 1936, page 52.

Wintry Maneuvers by G. H. Q. Air Force. Recent maneuvers to determine the effectiveness of equipment and personnel in the severest cold weather conditions of the Northeast. Clothing worn, three phases of the maneuvers, and types of aircraft used are described. U. S. Air Services, March 1936, page 13.

U. S. S. R.

What Exactly is the Aviation Strength of the Soviets? Probable aeronautical strength of the Soviets is placed at 8,000 to 9,000 airplanes, of which there are 3,000 military airplanes in active units, the majority being four-engined TB-3's, 2,000 airplanes in reserve, 1,000 in the schools, and 1000 in civil aviation. Les Ailes, January 30, 1936, page 10.

Air Transport

Flying the South Atlantic. R. S. Findley. Experience gained by France and Germany in flying the South Atlantic, and its value in establishing North Atlantic lines. U. S. Air Services, March 1936, page 32.

The German-South Atlantic Service—II and III. M. Sharp. Meteorological, radio, flying personnel, ground staff and equipment of the Deutsche Luft Hansa transatlantic airline are described in the second article. The third reviews costs, the Zeppelin proposition, new airplanes for the German service, and what the British could accomplish with such a service. Aeroplane, February 19 and 26, 1936, pages 235 and 267.

Spanning America in the Day. G. T. Marriner. Comments of a British visitor on the Boston-Los Angeles trip with particular reference to blind landing with passengers at Newark. Aeroplane, March 4, 1936, page 294.

Statistics

Aeronautical Data. The statistics given cover United States aeronautical exports and military and commercial airplane and engine production, 1926 to 1935, sales of military and commercial airplane parts, 1930 to 1935, scheduled transport operations of American air lines 1929–1935, and registrations of aircraft, gliders, pilots and glider pilots by states as of January 1. Automotive Industries, February 22, 1936, page 251.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.
Aero Digest, 515 Madison Ave., New York City.
Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.
L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.
L'Aerophile, 7 Rue Saint-Lazare, Paris, France.
The Aeroplane, 175 Picadilly, London, W.1, England.
L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.
Les Ailes, 77 Boulevard Malesherbes, Paris, France.
Aircraft Engineering, 112 Bunhill Row, London, E.C.1, England.
Air Law Review, Washington Square East, New York City.
Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.
Aviation, 330 West 42nd St., New York City.
Aviation Weekly, 9401 Western Ave., Los Angeles, California.
L'Aviazione, Corso Umberto 504, Rome, Italy.
Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.
Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.
Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.
Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.
Canadian Aviation, Journal Building, Ottawa, Canada.
Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.
Envol, 22 rue Armand-Moisant, Paris (15), France.
Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.
Flight, Dorset House, Stamford St., London, S.E.1, England.
Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.
Indian Aviation, P. O. Box 2361, Calcutta, India.
Journal of Air Law, Northwestern University, Chicago.
Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.
Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.
Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.
Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.
Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.
Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.
Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.
Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.
Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.
National Aeronautic Magazine, Dupont Circle, Washington, D. C.
Official Aviation Guide, 608 S. Dearborn St., Chicago.
The Pilot, Grand Central Air Terminal, Glendale, California.
Il Politecnico, Via Spiga 32, Milan (2/7), Italy.
Popular Aviation, 608 S. Dearborn St., Chicago.
Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.
Review of Scientific Instruments, 175 Fifth Ave., New York City.
Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.
Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.
Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.
Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.
The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.
Southwestern Aviation, Ledger Building, Fort Worth, Texas.
Sportsman Pilot, 515 Madison Ave., New York City.
Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.
La Technique Aeronautique, 2 rue Blanche, Paris (9), France.
U. S. Air Services, Transportation Building, Washington, D. C.
Western Flying, 420 S. San Pedro St., Los Angeles, California.
Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.
Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.